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Air Quality, Noise and Health: Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980

(U.S.) Panel on Air Quality, Noise and Health
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Air Quality, Noise and Health

Report of a panel of the

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Air quality projections during the timeframe 1980 to 2000 have been made for a variety of alternative levels of control for mobile sources. The resulting air quality projections are then compared to the national ambient air quality standards and selected health effects data to compare the impact of alternative control levels during the 1980-2000 timeframe. Finally, an analysis is conducted to assess the cost effectiveness of approaches to obtaining a given level of emissions reduction for the automotive related pollutants (carbon monoxide, hydrocarbons, and nitrogen oxides).

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Air Quality, Noise and Health

Report of a panel of the

INTERAGENCY TASK FORCE ON MOTOR VEHICLE GOALS BEYOND 1980

March 1976

INTERIM REPORT

Prepared by

The Panel on

AIR QUALITY, NOISE AND HEALTH

E. Tuerk, Environmental Protection Agency
Chairman

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Preface

As part of an interagency effort to evaluate various considerations involved in presenting motor vehicle goals beyond 1980, a separate panel under EPA direction analyzed the air quality, noise and health implications through the year 2000 of a variety of separate scenarios dealing with air pollutant and noise emission limits. These projections involved a series of assumptions as to growth, population impact, and future emission levels of sources other than light duty motor vehicles all of which influence the findings of the panel. Uncertainties abound in these types of projections and the discussion should be viewed in light of unknowns about which assumptions are made and conclusions presented. A special note of caution is offered with respect to the differences discussed in relation to various levels of air quality. There are many air quality benefits other than those presented in this report. No effort has been made to develop estimates of aesthetic benefit in relation to improved visibility nor of feelings of satisfaction from having cleaner rather than dirtier air. No assessment has been made of the improvement in the "quality of life" that would be expected as part of a successful air pollution control effort, nor has any effort been made to develop estimates of changes in property values that would be expected to accompany an improved urban environment.

The various health effect indicators chosen to present differences in air quality should be considered only a partial list. Quantification of health effect differences is a difficult undertaking and is based upon judgmental conclusions in areas where overt symptomatic differences have been observed. Indicators of a more subtle variety, such as chromosomal damage associated with oxidants and behavioral change associated with carbon monoxide, have not been quantified. The discussion here should be considered as being in the nature of a "best effort" but only a preliminary beginning in dealing with an immensely complicated subject.

The report considers only changes in levels of carbon monoxide, photochemical oxidants, and nitrogen dioxide, pollutants for which national ambient air quality standards have been developed. It does not discuss sulfuric acid emissions from motor vehicles which is the subject of a separate rule making action by EPA, nor does it discuss lead. EPA regulations requiring a phase down in lead additive use in gasoline are currently under judicial review.

Edward F. Tuerk
Chairman

SUMMARY

Air Quality - Introduction

Air quality projections during the timeframe 1980 to 2000 have been made for a variety of alternative levels of control for mobile sources. The resulting air quality projections are then compared to the national ambient air quality standards and selected health effects data to compare the impact of alternative control levels during the 1980-2000 timeframe. Finally, an analysis is conducted to assess the cost effectiveness of approaches to obtaining a given level of emissions reduction for the automotive related pollutants [carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx)].

Assumptions Used in the Projection of Air Quality

The projections of air quality are based on the assumptions summarized in Table I.

For light duty vehicles the new emissions standards are assumed to take effect in 1978 for hydrocarbons and carbon monoxide and in 1979 for nitrogen oxides. The replacement rate for light duty vehicles is assumed to provide for a turnover in vehicles every thirteen years. Deterioration rate of control devices for mobile sources is reduced from that presently occurring by assuming that inspection and maintenance plans will be in operation. The exhaust emission standards for light duty trucks, and gasoline and diesel powered heavy duty vehicles were projected based on estimated changes in emission standards. The emission reduction assumed for these vehicles is generally less than assumed for light duty vehicles.

Table I

ASSUMPTIONS FOR AIR QUALITY PROJECTIONS

Pollutant	Emission Source Category													
	Light Duty Vehicles					Other Mobile Sources					Stationary Sources			
	Emission Standards in Grams Per Mile*	Emission Factor Ratio of Emissions to Base Year**			Growth Rate Percent Compounded	Emission Factor Ratio of Emissions to Base Year				Growth Rate Percent Compounded	Emission Factor Ratio of Emissions to Base Year			Growth Rate Percent Compounded
		1980	1990	1999			1980	1990	1999		1980	1990	1999	
Carbon Monoxide	25.0	.32	.22	.22	1%	LDT	.35	.14	.14	1%	.85	.60	.45	3.2%
1970 Emissions = 77.1 grams per mile	15.0+	.32	.13	.13		HDG	.79	.29	.20					
	9.0	.31	.08	.08		HDD	1.00	.25	.20					
Emission Standards applied to model years 1978 and beyond	3.4++	.29	.04	.03		Average	.56	.19	.16					
Hydrocarbons/ Oxidants	2.0	.41	.21	.20	3%	LDT	.39	.14	.14		.85	.50	.25	3.2%
	1.5+	.40	.17	.17		HDG	.65	.18	.15	3%				
1970 Emissions = 10.3 grams per mile	.9	.38	.12	.12		HDD	.87	.27	.23					
	.4++	.37	.09	.08		Average	.53	.17	.16					
Emission Standards applied to model years 1978 and beyond	.1	.36	.06	.06										
Nitrogen Oxides	3.1 +	.83	.85	.86	3%	LDT	.87	.52	.52		.90	.70	.40	3.9%
1972 Emissions = 4.1 grams per mile	2.0	.76	.55	.55		HDG	.93	.58	.50	3%				
	1.5	.72	.44	.43		HDD	1.01	.53	.50					
Emission Standards applied to model year 1979 and beyond	1.0	.69	.30	.29		Average	.91	.54	.51					
	.4++	.65	.12	.10										
	.04	.63	.03	.01										

* Current emission standards apply until above changes occur.
**Emission factors are based on deterioration schedule presented in Table 2-2.
+ Present Interim Emission Standard.
++Statutory Emission Standard

For carbon monoxide a growth of one percent compounded annually was selected for all mobile sources. This is a lower growth rate than has been historically observed for metropolitan areas. It was chosen to reflect the fact that carbon monoxide is a localized problem where traffic density is already high and that growth in these areas will not be as great as for the broader metropolitan areas.

For hydrocarbons and nitrogen oxides a growth of three percent compounded annually was selected for all mobile sources. Hydrocarbons and nitrogen oxides are the precursors for oxidant and nitrogen dioxide formation. Oxidants and nitrogen dioxides are problems over wide areas and are not restricted to localized areas of high traffic density.

Stationary source growth rates were estimated from economic indicators for four groupings of sources: electric generation, industrial activities, area sources and other point sources. The sources of carbon monoxide and hydrocarbons are expected to grow at 3.2 percent compounded. Because of the expected increases in the use of coal for fossil fuel electric generation facilities a growth of 3.9 percent was assumed for nitrogen oxide sources.

A single scenario was modeled for stationary sources based on new control technology with successively more stringent controls being applied from 1980 to 1990 and 2000. The assumption about possible control technology was based on a review of existing technologies and technologies which are still under development. For the degree of control assumed, regulations in addition to the present regulations would be necessary to achieve the emission reductions.

Current Ambient Air Quality

Air quality monitoring data reveals that at least 65 Air Quality Control Regions (AQCR's) experienced violations of the eight hour (10 milligrams per cubic meter (mg/m^3)) carbon monoxide ambient standard during 1973. Available 1974 air quality monitoring data indicate that 43 of the above AQCR's experienced violations in 1974.

A review of 1973 and available 1974 air quality monitoring data reveals that there are at least 79 AQCR's in which violations of one hour ambient standard for photochemical oxidants (160 micrograms per cubic meter -(ug/m^3)) were experienced in one or both years.

Air quality monitoring data for the period 1972-4 indicate that at least 16 AQCR's are currently experiencing annual concentrations above the national ambient standard (100 ug/m^3) for nitrogen dioxide (NO_2). In addition, there are 14 more cities where the annual NO_2 concentration during 1972-4 was greater than 80% of the standard. It is estimated that NO_2 concentrations in at least 4 of these 14 cities will be above the national standards by the end of 1975.

Projections of Air Quality to the Year 2000

Projections of air quality to the year 2000 were made for carbon monoxide, photochemical oxidants, and nitrogen dioxide. The air quality projections are based on different emission standards for light duty vehicles using measured air quality and emissions inventories for a number of air quality control regions. Table II presents the average change in air quality from the early 1970 period to the year 2000. The percent of those cities which were modeled and which are still expected to have violations of the National Ambient Air Quality Standard in 2000 is also presented in this table.

Health Consequences Projections for Alternative Control Strategies

National health consequences projections are estimated for each of three future years (1980, 1990, 2000) and for the periods 1980 to 1990 and 1980 to 2000.

Carbon Monoxide

Although major reductions in health effects are projected under all scenarios and only limited adverse health effects estimated, nonetheless, during the period 1980 to 2000, adverse health effects are projected to be nine percent less if a 9 g/mi standard were implemented rather than continuing with the current interim emission standard of 15 g/mi. If a 3.4 g/mi standard were implemented, a thirty-nine percent reduction in health consequences is projected. Relaxing the emission standard to 25 g/mi would increase the projected adverse health consequences by forty-five percent.

Table II

SUMMARY OF AIR QUALITY PROJECTIONS

Pollutant	Light Duty Vehicle Emission Standard Grams Per Mile	Average Percent* Improvement in Air Quality from Base Year to 2000	Percent of Areas* with Violation of Air Quality Standard in 2000
Carbon Monoxide	25.0	67	37
	15.0	76	11
	9.0	80	0
	3.4	85	0
Photochemical Oxidants (Hydrocarbon control)	2.0	39	86
	1.5	41	84
	0.9	46	76
	0.4	50	70
	0.1	52	62
Nitrogen Dioxide	3.1	-29	52
	2.0	-13	33
	1.5	- 7	33
	1.0	0	19
	0.4	10	19
	0.04	15	19

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*Based on selected cities and geographic divisions

Photochemical Oxidants

During the period 1980 to 2000, the total adverse health effects are projected to be eighteen percent less for aggravation of heart and lung disease, asthma and cough if a 0.9 g/mi standard were implemented rather than continuing with the current standard of 1.5 g/mi. If the 0.4 g/mi standard were implemented in 1978, it is projected that the aggravation of these ailments would be reduced by 24% over the 1980 to 2000 period. The benefits are most apparent for the year 2000 as the change from 1.5 g/mi to 0.4 g/mi is estimated to cause a 45% reduction in the aggravation of these ailments.

Nitrogen Dioxide

Significant differences exist over the period 1980 to 2000 for respiratory attacks projected by continuing with the current 3.1 g/mi nitrogen oxides emissions standards versus implementing either a 2.0 g/mi or the statutory standard of 0.4 g/mi. A 53% reduction in respiratory diseases disability attributable to NO_2 exposure is anticipated over this time period if the statutory standard were implemented. The benefits of implementing the statutory standard are most apparent in the per year estimates for the year 2000, as a 69% reduction is projected for that year.

Cost Effectiveness of NOx Control

In terms of reductions of total tons of NOx removed increasingly stringent emission controls are decreasingly cost effective. From 3.1 to 2.0 g/mi the cost is approximately $165/ton of NOx removed; from 2.0 to 1.0 g/mi the cost is approximately $450/ton of NOx removed and going from 1.0 to 0.4 g/mi costs approximately 2300/ton of NOx removed.

Various stationary source controls fall within the range of LDV cost effectiveness estimates.

Cost Effectiveness of Hydrocarbon Control

On a cost effectiveness basis more stringent control over a variety of stationary sources emissions and in gasoline handling procedures rank above reducing LDV emissions to the statutory 0.41 g/mi standard. However, it is clear from the high degree of emission reduction needed to attain the national standard for oxidants in many cities, that implementation of all measures may still not result in attainment of the oxidant standard.

Feasibility of a Two Car Strategy

The benefits of a two car strategy that allows a small percentage of the new cars to meet a less stringent emission limitation (assuming statewide application of the strategy) would be outweighed by the problems that would affect auto manufacturers, consumers, and control officials as a result of such a strategy.

Noise

The projection of potential benefits which could be derived from reductions of automobile noise emission levels are described in terms of the percent reduction in the extensiveness and severity of noise impact as determined from changes in the equivalent number of people impacted.

The potential health and welfare benefits resulting from reductions of automobile noise are presented for urban street traffic only (medium to high density urban setting with stop-and-go driving and periods of urban acceleration and low speed cruise), since (1) the number of people impacted by urban street traffic is much greater than the number impacted by freeway traffic noise, and (2) it is assumed that freeway noise will be substantially reduced by tire noise regulations in addition to vehicular propulsion noise.

The results clearly demonstrate the fact that effective reduction of urban noise is contingent upon the regulation of noise emissions from all surface transportation vehicles, not just automobiles.

Although primary benefits in terms of reduction in extensiveness and severity of noise impact are associated with reductions of automobile noise under accelerating conditions, substantial additional benefits are realized by a concurrent program reducing noise emissions under normal cruise conditions. Specifically, there is projected 66 percent reduction in the extensiveness and severity of impact when automobile urban acceleration noise is reduced to 60 dB(A), while a 75 percent reduction in impact is achievable when both acceleration and low speed cruise emissions are reduced to 60 dB(A) and 50 dB(A), respectively. The urban acceleration noise emission is expected to average 11 dB(A) less than the emission measured under the SAE J986(a) test for maximum acceleration.

The most substantial relief will be afforded to that segment of the population that is exposed to primarily vehicle urban acceleration noise, culminating in an 80 to 87 percent reduction in impact when accelerating noise emissions are reduced below 60 dB(A).

Furthermore, very substantial benefits can be realized by those people primarily exposed to automobile noise, i.e., in those areas where trucks, buses, and motorcycles are either prohibited or do not normally operate. Benefits in this latter case are approximately a 72 percent reduction in noise impact when urban acceleration noise is reduced to 60 dB(A) and 100 percent reduction (no impact) when levels are reduced to 60 dB(A) and 50 dB(A) for acceleration and normal cruise modes, respectively. Of particular note is the fact that completely eliminating automobile noise would effect only an approximate 78 percent reduction in noise impact to the whole population, and 88 percent relief to that portion of the population exposed to only vehicle acceleration noise where a vehicle mix including about 9% trucks, buses, and motorcycles is allowed to operate.

In view of the above results, an effective long-term goal for automobile noise emissions, as measured at 50 feet, without regard to economic or technological feasibility, is in the range of 71-75 dB(A) for passby urban acceleration noise (corresponding to approximately 69-73 dB(A) under SAE J986a). Additional benefits may be realized if noise emissions are reduced such that at a 27 mph road load and lower speeds, automobiles emit only 50-56 dB(A) as observed at 50 feet.

1.0 Introduction

1.1 Background

On March 21, 1975, Secretary Rogers C. B. Morton, Chairman of the Energy Resources Council, requested that the Secretary of Transportation lead a joint Federal task force to examine long-range energy goals of the motor vehicle fleet, compatible with environmental, safety and economic objectives. The Task Force consists of representatives from the Federal Energy Administration, the Energy Research and Development Administration, the Environmental Protection Agency, the National Science Foundation and the Department of Transportation and others.

The task force was directed to:

1. Examine the present state of knowledge for motor vehicle emissions, noise, safety, damageability, fuel economy, performance and cost.
2. Relate the national goals of air quality, noise reduction, highway safety, vehicle damageability and energy conservation to the characteristics of the present and projected motor vehicle fleet, to the economy and to public health and mobility.
3. Determine feasible levels and timing for motor vehicle emission, noise, safety, damageability and fuel economy objective beyond 1980 and determine the process whereby these objectives could be established in a balanced manner.

4. Evaluate alternative policies, their benefits and costs and feasible implementation strategies to achieve national goals.

5. Provide for public hearings in carrying out its mission.

The period of time being considered is the decade beginning 1980. Representatives of more than 20 agencies of the U.S. Government constitute the membership of the panels.

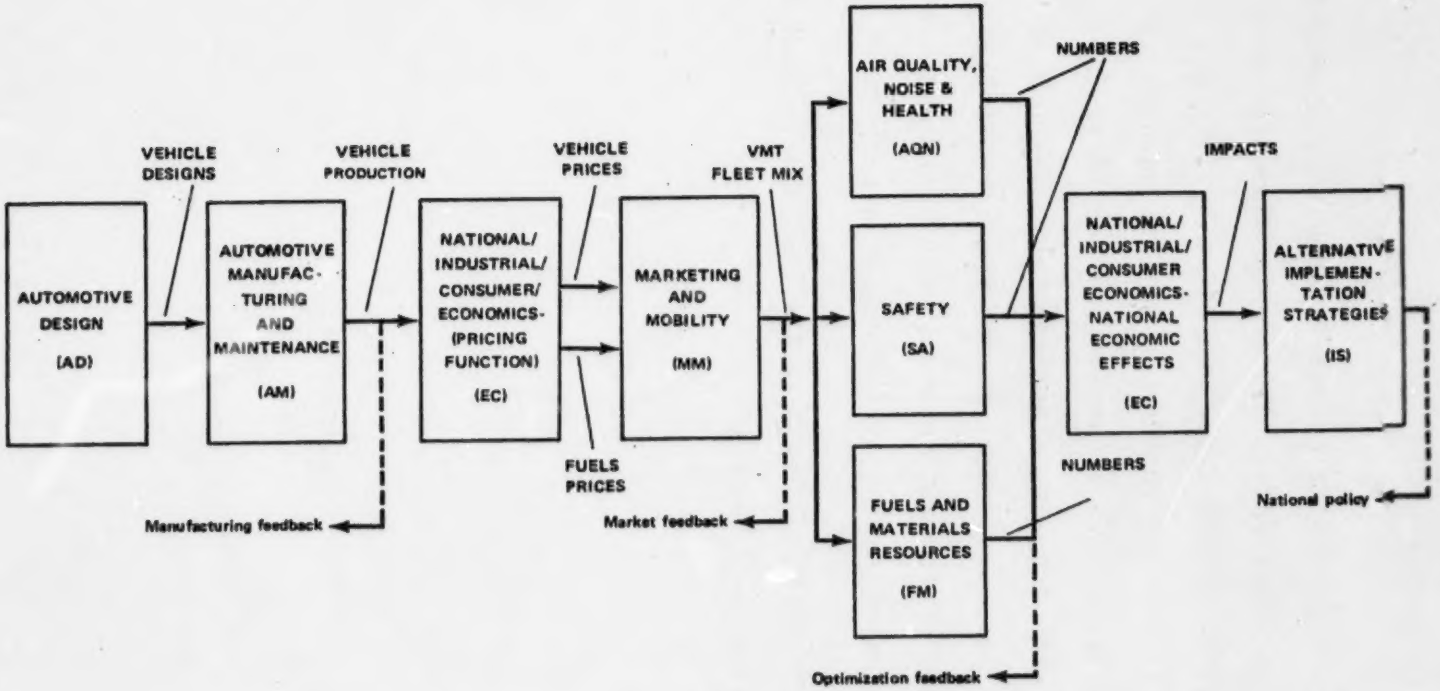
Eight special panels within the Task Force were established to address major impact areas. These panels include Air Quality, Noise and Health; Safety; Fuels and Materials Resources; Automotive Design; Automotive Manufacturing and Maintenance; Marketing and Mobility; National/Industry/Consumer Economics; and Alternative Implementation Strategies.

The reports of the panels will provide the data base for the Task Force report. The latter will describe the analysis of realizable automotive design goals, their impacts on the National, consumer, and industrial economies, and the alternatives for Government actions to facilitate the design goals.

The analysis will compare a number of alternative designs. Each design represents a different compromise of competing considerations for reduced vehicle emissions and noise and enhanced safety and fuel economy. For each design, there will be a definition of strategies for implementing rational policies with respect to automobiles. The report will describe the merits and demerits of the several design alternatives and of the alternatives for Government actions to facilitate realization of the design alternatives.

The sequence of steps in the analysis of each design goal is shown in Figure A.

Figure A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National policy

1.0 INTRODUCTION

1.2 MOTOR VEHICLE CONTRIBUTION TO AIR POLLUTION

In establishing the Clean Air Act (CAA) amendment of 1970, Congress recognized that mobile sources contributed significantly to the nation's air pollution problem. Consequently, very stringent levels of control for certain classes of motor vehicles were established by Congress and broad authority was delegated to the Environmental Protection Agency to establish needed controls on the other mobile sources.

As the nation has progressively moved toward obtaining the level of mobile source emission control envisioned by Congress in 1970, many problems have been encountered. The current world energy situation, the economic recession, and the failure of technological developments to simultaneously provide good fuel economy and emission reductions, are a few of the problems causing considerable debate over the need and wisdom to control emissions from mobile sources to the level originally established by Congress.

In light of the current debate over mobile source emission control, and the need to develop programs which will ensure that the goals of the CAA are achieved, it is prudent to investigate the potential impact mobile source emissions will have on future air quality and subsequently the health and welfare of the nation. To accomplish this task, air quality projections during the time-frame 1980 to 2000 have been made for a variety of alternative levels of control for mobile sources. The resulting air quality projections are then compared to the national ambient air quality standards and health effects data to assess the impact each alternative control strategy will have on the nation's population during the 1980-2000 time-frame. Finally, an analysis is conducted to determine the most cost-effective approach to obtaining a given level of emissions reduction for the automotive related pollutants [carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x)].

1.2 REVIEW OF PROVISIONS IN THE CLEAN AIR ACT

Before discussing the techniques used and the results of the present study, a brief review of the CAA, the provisions for controlling air pollution contained therein, and a brief historical account of events since 1970 is needed in order to better understand the discussion that follows.

With the enactment of the Clean Air Act (CAA) amendments of 1970, Congress set forth a hational program for ensuring that the quality of the air is sufficient to protect the health and welfare of the nation. The Environmental Protection Agency (EPA) was established in 1970 and given the responsibility for seeing that the provisions of the Act were carried out.

The CAA provides EPA with six major means for controlling air pollutants: (a) National Ambient Air Quality Standards (NAAQS), (b) Standards of Performance for New Sources (NSPS), (c) National Emission Standards for Hazardous Air Pollutants (NESHAP), (d) Emission Standards for Motor Vehicles, (e) Regulation of Fuel, and (f) Aircraft Emissions.

NAAQS, which represents maximum allowable concentrations of a pollutant in the ambient air, may be established for any pollutant which has adverse effects on public health and welfare when the ambient levels of the pollutant results from numerous or diverse mobile or stationary sources. The need for, and the value of, a NAAQS is determined through a detailed study of all available information on the effects of the pollutant on public health and welfare. The results of this study are made available in a criteria document. Two levels of a NAAQS may be set if necessary: (a) a primary standard, which assures (with an adequate margin of safety) that the public health is protected, and (b) a secondary standard designed to protect the public welfare, such as soil, vegetation, man-made materials, animals, weather, visibility, or personal comfort and well-being.

Once a NAAQS is established, states must develop, and EPA must review and approve, an implementation plan which provides for sufficient control of sources which emit the pollutant so that the NAAQS will be attained. The adequacy of the control measures developed by the states for attaining NAAQS is based upon air quality control regions (AQCR's), which are areas bounded (as much as possible) by air having the same quality. Currently there are 247 such regions throughout the United States and its territories.

NAAQS have been established for five pollutants; Particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and photochemical oxidants. In addition, an ambient "guideline" has been set for non-methane hydrocarbons which, if met, would ensure that the NAAQS for photochemical oxidants will be met.

Under the provisions of the CAA of 1970, attainment of a NAAQS must be accomplished within three years after the states' implementation plans are submitted, except in situations where control technology is unavailable. In these latter situations a two-year extension of the attainment date may be granted. Thus, the latest attainment date for any of the five NAAQS above is July 1977.

The CAA of 1970 requires EPA to set "standards of performance" for new and "modified" stationary sources of pollutants which contribute significantly to the endangerment of public health or welfare. These standards, frequently referred to as New Source Performance Standards (NSPS), differ from NAAQS in that they apply to specific source categories and establish an emission limitation for those source categories on a national basis. Generally they apply to new sources, but are also applicable to existing sources whenever "modification" (physical change or change in the method of operation) results in an increase in emissions of old pollutants or emissions of a new pollutant. NSPS must be based upon best demonstrated control technology considering cost. To date NSPS have been promulgated for 12 source categories and proposed for 8 more.

NESHAP are established for those pollutants which EPA believes "may cause, or contribute to, an increase in mortality or . . . in serious irreversible, or incapacitating reversible, illness" (Section 112 of

CAA). NESHAP for asbestos, mercury, and beryllium have been promulgated to date.

Congress, through the CAA of 1970, set deadlines for controlling major emissions from mobile sources. The Act originally required that beginning with the model year 1975, carbon monoxide and hydrocarbon emissions from automobiles and light duty trucks must be reduced by at least 90 percent from the 1970 partially controlled levels. The Act further requires that NO_x emissions from model year 1976 autos be reduced by at least 90 percent from the uncontrolled 1971 levels. EPA was given authority to postpone for one year the above deadlines for control of automobiles and light duty trucks. The Agency was also charged with establishing emission limitations for other classes of mobile sources.

The emission reduction for automobiles and light duty trucks are frequently referred to as statutory standards, and have been determined by EPA to be represented by numerical values of:

HC: 0.41 grams/mile
CO: 3.40 grams/mile
NO_x: 0.40 grams/mile

The Act requires that the above standards be met over the useful life of the motor vehicle, defined by Congress as the first 50,000 miles or 5 years, whichever comes first. The Act also allows EPA to establish standards for automobiles and light duty trucks manufactured during the interim period of 1970 to 1975.

On April 11, 1973, the Administrator of EPA granted a one year suspension of the statutory standards for carbon monoxide (CO) and hydrocarbons (HC). Interim standards for all states except California were set at 1.5 gm/mile for HC and 15.0 gm/mile for CO. Separate standards of 0.9 gm/mile HC and 9.0 gm/mile CO were prescribed for the cars sold in the State of California. On July 30, 1973, the Administrator further granted a one year suspension of the statutory NO_x standard.

In June 1974, Congress enacted amendments to the Clean Air Act in the Energy Supply and Environmental Condition Act (ESECA) which provided for a continuation of the 49 state standard (1.5 gm/mile HC and 15.0 gm/mile CO, through model year 1976 with the statutory standards to be effective in 1977. Under ESECA the Administrator of EPA was authorized to grant a one year extension of the statutory standard to model year 1978. ESECA established an interim NO_x standard of 3.1 gm/mile effective in 1976, 2.0 gm/mile in 1977 and required the statutory NO_x standard (0.4 gm/mile) to be effective with model year 1978. Standards for the State of California for 1976 and 1977 are 0.9 gm/mile HC, 9.0 gm/mile CO, and 2.0 gm/mile NO_x.

On March 15, 1975, the Administrator granted a one year extension of HC and CO standards to model year 1978. At the present time, Congress is considering several proposed amendments to the Act which would further delay the deadlines for meeting the statutory standard for automobiles. EPA has used its authority to control fuel additives, by establishing a limit on the lead content of gasoline. This regulation is currently being contested in the courts.

2.0 METHODOLOGY - AIR QUALITY

2.1 INTRODUCTION

This report presents analyses which project air quality to the year 2000, which relate this air quality to health, and which compare the costs of various options for control of emissions. The projections of air quality, health, and costs of control are based on the best information available. Because of the major assumptions that are made about trends over a long time period, the results must be used with caution. The results are intended to indicate the relative merits of various control scenarios. The trends that are indicated for the various scenarios are likely to occur; however, the actual numbers presented are subject to uncertainty because of the various assumptions made. The methodology and assumptions used in these analyses are presented in the following sections.

Long-range projections require assumptions different from those used for short-range projections. For example, in this report the assumed growth rates to the year 2000 are lower than recent trends would indicate. Also scenarios with more extensive control technology than is presently available are considered. For this reason the concentrations of pollutants that are given in this report for 1980 and possibly 1990 are not as high as are actually expected. Other references[1] should be used for short-range projections to 1980 and 1985.

Because of the gross assumptions that must be made about costs of new and even existing technology for pollution control to the year 2000, only national cost estimates were made. Because of the uncertainties in costs, it would not be proper to calculate projected costs for each area or city of the country. It must be understood, of course, that actual control strategies will vary from area to area because the ratio of mobile to stationary sources of emissions, and the make-up of the stationary sources, varies from region to region. The different emission sources in the base year are accounted for in the air quality projections.

Prediction of health effects from air quality requires additional assumptions. Recent reports have attempted to analyze the problems in the prediction of health effects for the pollutants associated with mobile sources.[2-4] The caveats are presented in the sections on health effects.

2.2 PROJECTING AIR QUALITY FOR FUTURE YEARS

This section presents the basis for the method used to project air quality in this study. It also discusses the limitations, sources of error and uncertainties of the method so that the precision of the projections can be estimated. A comparison of calculated air quality and measured air quality trends is also included. Specific assumptions that are used for each pollutant are also discussed.

2.2.1 THE PROJECTION MODEL

Projecting air quality into the future is a two-step process as shown in Figure 2-1. Changes in emissions from a base year are estimated from growth, changes in control technology, and changes in emission sources. The change in air quality is then calculated from the projected change in emissions.

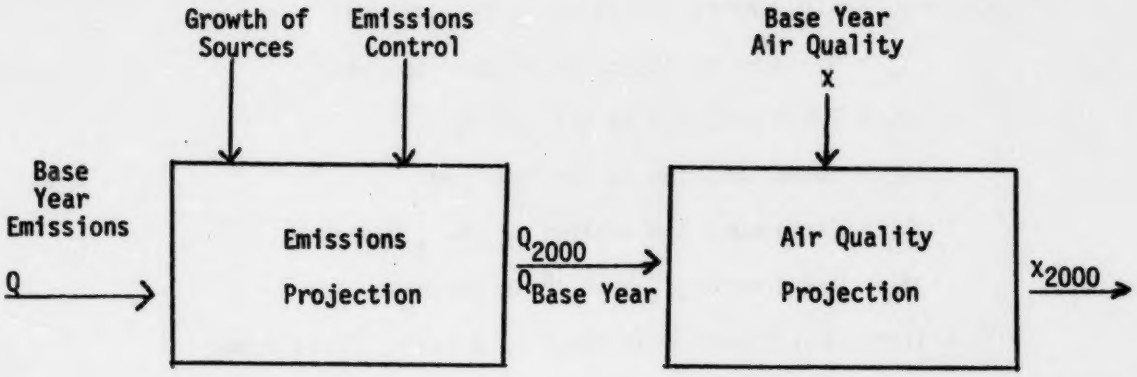
Growth of Sources
Emissions Control
Base Year Air Quality
X
Base Year Emissions
Q
Emissions Projection
Q2000
QBase Year
Air Quality Projection
X2000

Figure 2-1. Projections of Air Quality to the Year 2000

The simplest relation between emissions and air quality is based on the assumption that the change in air quality due to man-made sources of pollution is proportional to the change in man-made emissions in the region of interest.[5] This relationship is given in the form:

$$\frac{X_j - B_j}{X_o - B_o} = \frac{Q_j}{Q_o}$$

where X_j = Air Quality indicator in the $_j$th year

X_o = Air Quality indicator in the base year

Q_j = Total emission in the $_j$th year

Q_o = Total emission in the base year

B_j = Background air quality in the $_j$th year

B_o = Background air quality in the base year

This linear relationship or model is a valid, first order approximation of reality if the following assumptions are supportable:

1. The distribution of emissions in space and time is relatively stable over the projection period, and

2. The meteorological and topographical characteristics of the area are stable over the projection period.

It is to be noted that this model does not predict air quality from emissions, but only relates changes in air quality to changes in emissions. For example, the total emissions for some pollutant in Cleveland may be similar to the emissions in Houston, but the air quality may be much different for the two cities because of different meteorological and topographical conditions. The model merely assumes that changes in the air quality in Houston will be proportional to changes in the emissions in Houston, and that changes in the air quality in Cleveland will be proportional to changes in the emissions in Cleveland. The constants of proportionality are, in general, different.

The background air quality includes the pollutants advected into the region and the concentration of the pollutant generated from natural sources within and near the region. The background air quality is that concentration which would be expected if there were no man-made emissions within the region. Usually, background air quality must be estimated because of the lack of data outside urbanized areas. It is expected that background levels may change with time because of changes in emissions in regions adjacent to the region of interest.

Errors enter this model because of errors in determining the base-year emissions inventory and errors in projecting emissions.

In general the emissions inventories are for annual averages, and therefore the air quality projections are best applied to annual air quality indicators. It is assumed that trends in short-term air quality indicators also follow the trends in average emissions.

Errors also occur because large new sources of emissions may be added to a region and grossly alter the emission distribution. Therefore, the linear model should not be expected to predict accurately the change of concentration at each and every monitor, but it can be used to estimate the change in average air quality over the urbanized area due to emission changes which are distributed over that area. Another error enters the projection because changes in air quality may not be proportional to changes in emissions. It is expected that, for primary pollutants which do not have rapid reactions in the atmosphere or do not decay rapidly, the linear model is acceptable. For pollutants which are reactive, such as hydrocarbons, nitrogen dioxide, and oxidants, the linear model is a first order approximation to the processes which are non-linear. For long-term projections, the error caused by assuming linearity between emissions and air quality is small compared with the uncertainties in the projection of emissions and the uncertainty in the choice of air quality indicator. For oxidants, a non-linear relationship between oxidant concentration and hydrocarbon emissions has been developed from observed data and is included in the model (see Section 2.2.3.2).

When air quality data are used to predict health effects it must be assumed that the measured air quality in the base year is representative of the air quality in the region of interest. Because air quality data are usually measured by point monitors, they provide a good temporal profile but may not be good indicators of the distribution of pollutant concentrations. Point monitors are highly influenced by emissions in the local vicinity, although they may not be located at the point of maximum regional concentration. In this study, the concentration used for the base year was the maximum concentration observed within an air quality control region over a period of several years.

2.2.2 PROJECTION OF EMISSIONS

In order to consider explicitly all emission sources, the emissions from all sources for a pollutant are disaggregated into a number of mobile and stationary sources. The model actually used for projecting air quality is:

$$\frac{X_J - B_J}{X_o - B_o} = \frac{\Sigma_I Q_I G_{IJ} F_{IJ} K_I}{\Sigma_I Q_I K_I}$$

WHERE J = CALENDAR YEAR INDEX

I = SOURCE CATEGORY INDEX

Q_I = BASE YEAR EMISSION INVENTORY

G_{IJ} = GROWTH FACTOR

F_{IJ} = EMISSION FACTOR RATIO

K_I = SOURCE CONTRIBUTION FACTOR

X_J = PROJECTED AIR QUALITY CONCENTRATION

B = BACKGROUND

X_o = BASE YEAR AIR QUALITY CONCENTRATION

The various factors included in this model are: G, the growth; F, the ratio of emissions from a source in the projection year to its emissions in the base year, per unit of production; and K, a source contribution factor to account for the fact that emissions released from a height or at a distance may have less impact than emissions in the vicinity of the receptor. The factor K is used only in the projection of carbon monoxide concentrations. For mobile sources, the emission factor ratio, F, is determined as the pool of existing vehicles which changes annually as old vehicles are replaced and control systems deteriorate.

Three major source categories are presented in this study. They are light duty vehicles, other mobile sources, and stationary sources.

The growth rates and degrees of control for each of these source categories were determined by accounting for specific sources within each category.

Base year emissions are derived from inventories collected by states and submitted in State Implementation Plans. In some cases, more recent inventories have been made and placed in the National Emission Data System (NEDS) and are used for this study. These emission estimates are for annual averages and therefore may not accurately represent the emissions at the time of the observed air quality.

Each Air Quality Control Region will have a different ratio of mobile to stationary sources. Therefore projected emissions will be different for each area because of the different growth rates for different sources.

The largest unknown in the projection model occurs in the estimates of growth and in future technology and control regulations. A number of mobile source emission control standards are presented as scenarios in this study. The best estimates for future national growth and stationary source emission reduction technology were assumed. It is expected that some areas of the country will experience greater growth than other areas. Some areas may also require more stringent control than will other areas.

It is also expected that growth will not continue at a constant rate for the study period. Other questions which lead to further uncertainty are, for example, what will be the growth in fossil fuel electric generation? Will this growth be in new regions of the country, in rural areas or near metropolitan regions? These and other questions are contained in the projections of emissions. The specific assumptions are discussed in Section 2.3 and in the discussion of cost effectiveness in Section 5.0.

2.2.3 PROJECTION OF AIR QUALITY

The air quality projections for each of the three pollutants are somewhat different. These will be discussed separately.

2.2.3.1 CARBON MONOXIDE

Since the "hot spots" for CO are always located in areas of high traffic density the impact on future air quality of mobile source emissions and their control appears to dominate the CO situation; stationary sources have very little impact. Therefore, it is necessary to apply an adjustment factor to the stationary source categories to realistically estimate future air quality. Factors of .20 for area sources, .10 for industry and 0 for power plants were used. This means that a pound of CO from a new industrial source was assumed to have only 1/10 the air quality impact on the roadside CO "hot spot" as a pound of CO emitted on the street in front of the sampler. These adjustment factors were selected after considering the results from dispersion models for power plants and industry and a review of the relationship between traffic density and CO levels in several situations.

Because CO does not react rapidly in the atmosphere, the assumption of linearity between the changes in CO concentration and the changes in emissions near the monitor is good. Measurements of ambient CO concentration, however, are not good indicators of regional air quality, because CO concentrations are very localized. Moving a monitor a few feet from curb to sidewalk will cause a large change. High CO concentrations are found at busy intersections, street-side, and at other locations of high traffic density. The most direct measurement of the effect on humans of ambient carbon monoxide would be the percent of blood carboxyhemoglobin in a representative sample of the population. The relationship between air quality and carboxyhemoglobin levels has been presented in several studies.[6-8] The results of these studies were used to provide the relation between measured air quality and health effects.

An eight-hour average background concentration of 1 ppm is assumed for carbon monoxide.

2.2.3.2 HYDROCARBONS AND OXIDANTS

Photochemical oxidants are not emitted directly into the atmosphere but result primarily from a series of chemical reactions between oxidant precursors (nitrogen oxides and organic compounds) in the presence of sunlight. The principal sources of organic compounds are the hydrocarbon emissions from automobile and truck exhausts, gasoline vapors, paint solvent evaporation, open burning, dry cleaning fluids, and industrial operations. There are also natural sources such as seepage from the ground and emissions from vegetation. Nitrogen oxides are emitted primarily from combustion sources such as electric power generation units, gas and oil-fired space heaters, and automobile, diesel and jet engines.

Nitric oxide (NO) is the major form of nitrogen oxide emitted in combustion processes. Nitrogen dioxide (NO_2) is formed from NO and is the compound which decomposes in sunlight to initiate the formation of ozone.

The factors which determine the concentrations of oxidants formed in the atmosphere include: (1) the amount and kinds of organic compounds initially present and the rate at which additional organics are emitted to the atmosphere; (2) the amount of nitrogen oxides initially present and their emission rates; and (3) sunlight ultra-violet intensity, temperature, and other meteorological factors. The interactions of these factors and the chemical reactions involved are very complex and have been the subject of continuing scientific investigation during the last 20 years, including atmospheric studies, laboratory smog chamber studies, and computer simulation of the oxidant forming process.

Because the relationship between hydrocarbon emissions and oxidant concentrations is dependent on so many factors, various attempts have been made to develop a simplified relationship. One such approach has been the use of an upper-limit curve which encloses the highest oxidant values observed for a given hydrocarbon concentration. Such a curve was presented in "Air Quality Criteria for Nitrogen Oxides"[9] and was the basis for Appendix J to the August 14, 1971 Federal Register notice entitled "Requirements for Preparation, Adoption, and Submittal of Implementation Plans."[10] More recent data have extended this upper limit curve to higher concentrations of oxidants as shown in Figure 2.2[11].

This graph therefore provides a non-linear relationship between hydrocarbon emissions and the second highest hourly concentration of oxidants within an urban area. The relationship has many inherent weaknesses, but it represents an approximation to the complex set of reactions

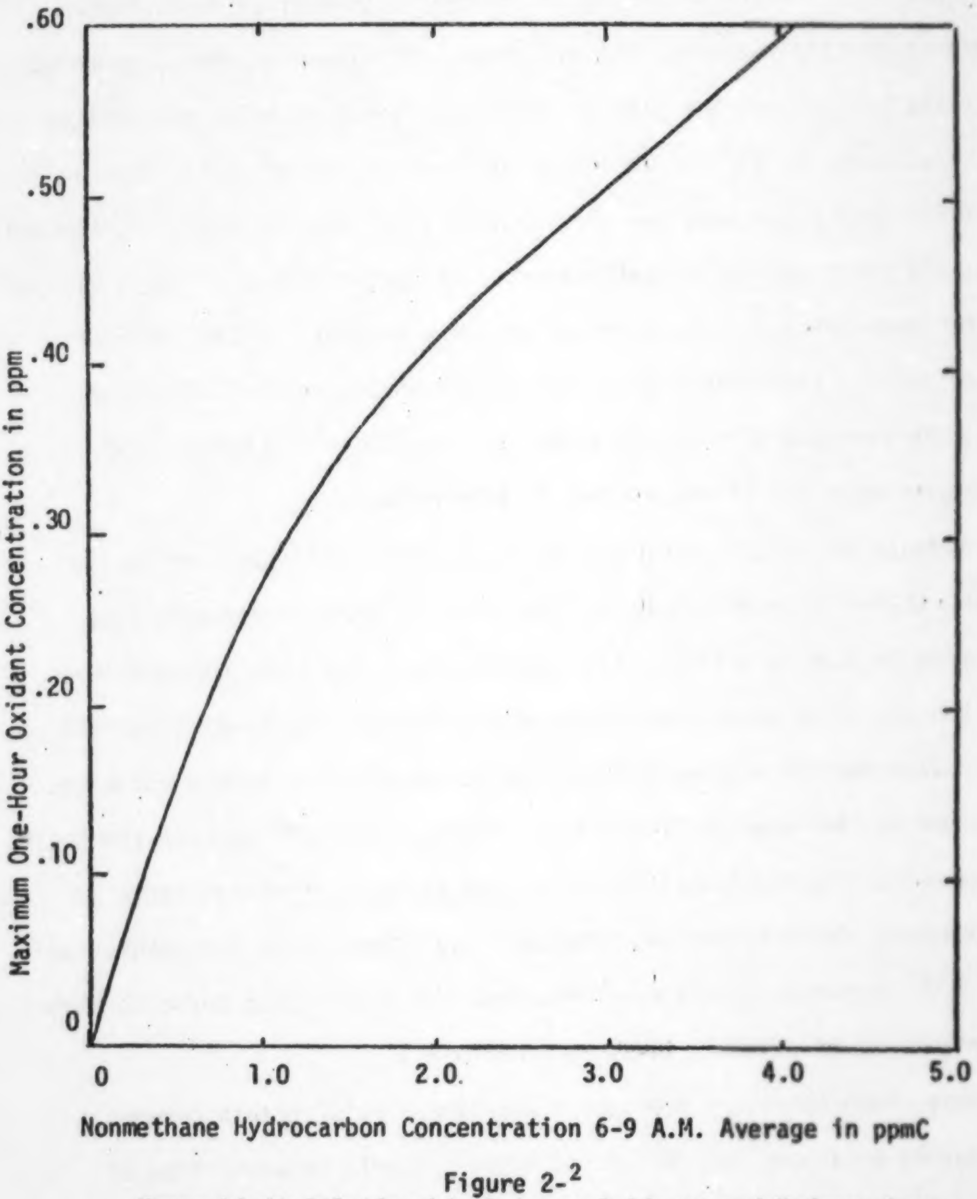

Figure 2-[2]
Upper Limit Relationship Between Oxidants and Hydrocarbons

which determine the relationship between hydrocarbons, nitrogen oxides and photochemical oxidants.

The application of the upper-limit curve assumes that there is no background of oxidants in an urban atmosphere (i.e., all emissions are assumed to be from man-made sources within the appropriate AQCR and no oxidant is transported from surrounding areas.) The modeling technique does not entirely neglect the oxidant background, since the measured air quality data used for the base year includes any background concentration. However, in making the air quality projections, the oxidant concentration due to background is not distinguished from that due to man-made emissions within the AQCR. Consequently, the results imply that background concentrations will change in the future and this change will be proportional to the changes in man-made emissions.

In reality, background oxidant concentrations have no dependency upon man-made emissions within the AQCR and, therefore, some error is introduced through the technique used for estimating future air quality. It is believed that in most urban areas, the oxidant background concentration from natural sources ranges between .01 and .05 ppm,[12] and consequently the assumption of zero background does not introduce significant errors in the projected air quality. As an example, for a net reduction from base year emissions of 50%, the future air quality projection would be approximately .025 ppm lower for a zero background situation than for one in which the base year background was .05 ppm. The effect of a background concentration is that air quality improvement will be less than proportional to emission reductions. This is the same effect which the upper-limit curve displays, i.e. a more than proportional reduction is required to achieve a given improvement in air quality.

The exact level of background oxidant is not known. It is expected that the level varies from city to city. While it is possible to use estimated values for the different cities, it is not believed that these estimates would add significantly to the results of this study. Nitric oxide emissions within a city act as a scavenger for the oxidant and tend to reduce the oxidant concentration advected into a city. This provides some further justification for neglecting background in the air quality projections.

Neglecting oxidant background in the air quality projections is not believed to constitute large errors in the health projections. As previously discussed, for most urban areas the oxidant background from natural sources is believed to be less than .05 ppm. Consequently, on days when air quality is near the ambient air quality standard of 0.08 ppm for oxidants, background could make up a large percentage of the ambient oxidant. Under this situation the background would be expected to have its most pronounced effect. However, when air quality is at this level, the health effects are confined to relatively few people. On the other hand, on days when the ambient oxidant level is substantially above the air quality standard, the effects of background oxidant will be overshadowed by the oxidant from man-made sources. It would be expected that the health effect projections sould be somewhat greater than projected in this study, if background were taken into account.

2.2.3.3 NITROGEN OXIDES AND NITROGEN DIOXIDE

Almost all NO_x is emitted as NO. The rate at which NO is converted to NO_2 is a function of many factors, including hydrocarbon concentrations, hydrocarbon reactivities, ultraviolet radiation intensity, ambient temperature, etc. During the increment of time required for NO to convert to NO_2, these two compounds are being dispersed. A portion of the total NO plus NO_2 (NO_x) from power plants is being brought to the ground while a portion of that emitted from motor vehicles is being dispersed upward. The NO_x is being mixed throughout the urban atmospheric environment and it becomes reasonably ubiquitous. Generally, sharp gradients of NO_2 are not observed in an urban setting. In addition, for the projections of this study only an annual average NO_2 is projected. Under these circumstances, it is not critical that the spatial or temporal variations in concentration be identified and the linear model is a good first approximation.

The background for NO_2 is assumed to be an annual average of 8 $\mu g/m^3$.

2.2.4 ADEQUACY OF THE PROJECTION MODEL

A retrospective comparison of past air quality data with model projections into the past is one method to determine the adequacy of the assumptions used in the model. While the assumptions made in the projection model are thought to be reasonable for predicting trends in concentrations, the relationship may become less valid as the real situation deviates from the assumed situation.

The Los Angeles AQCR has the most extensive set of air quality data with which to compare the projections of the model. The model was used with known California emissions standards and base year air quality data and growth rates for 1970 or 1972. The air quality was projected for 1964 and 1974 and compared with air quality data from several monitoring locations within the Los Angeles AQCR.

For carbon monoxide the model projected a decrease in the eight-hour maximum concentration of approximately ten percent from 1964 to 1970 and approximately twenty-two percent from 1970 to 1974. The measured air quality data does not show a smooth change, but rather has large variation from year to year and between monitoring sites. While the projection model was not intended to, nor did it, show these large year to year variations, it did follow the generally observed trends. For seven monitoring sites in the Los Angeles AQCR the average change in the eight-hour maximum concentration decreased seventeen percent between 1970 and 1974 compared with the projected twenty-two percent decrease. At Pomona there was an increase in concentration of five percent, while at downtown Los Angeles there was no change, and at Long Beach there was a decrease of more than fifty percent over this period.

For oxidants, the measured second-high one-hour concentration also had great variation between sites and from year to year. From 1964 to 1970 the average change for six sites was an increase of 1.5 percent. However, from 1965 to 1970 the average change was a decrease of twenty-three percent. The model projected a smooth decrease in the second high maximum concentration of seven percent from 1964 to 1970 and a nine percent decrease from 1970 to 1974. The average measured air quality decreased by twenty-one percent from 1970 to 1974 for the six locations. These measured changes and variations are considerably greater than projected by the model. This difference may be due to the simplification of the chemical processes in the model and the fact that changes in nitric oxide emissions are not included in the model.

For the nitrogen dioxide annual average concentration, the model projected an increase of forty-two percent from 1964 to 1972 and a continued increase of six percent from 1972 to 1974. At the downtown Los Angeles site the measured change was thirty-eight percent between 1964 and 1972. The increase for the West Los Angeles site during this period was twenty-eight percent. These are the only two sites for which air quality data are available in the Los Angeles AQCR for this period. Both sites also show an increase in nitrogen dioxide from 1972 to 1974. Similar trends in nitrogen dioxide air quality have been observed at CAMP stations in other cities.

In general the model predicted past air quality trends which were similar to measured values. For oxidants, the observed decrease since 1965 was greater than predicted. Differences between observed and predicted air quality may be due to errors in estimating emissions, or to localized changes near monitoring sites, or to simplifications in the relationship between emissions and air quality. Whether the model has the ability to predict future air quality within the ranges covered in the report is unknown. The relative changes between scenarios would be expected to be more precise than the actual projected values.

2.3 ASSUMPTIONS USED IN THE PROJECTION OF AIR QUALITY

The projections of air quality are based on the scenarios summarized in Table 2-1. These scenarios include a number of emission standards for light duty vehicles and other mobile sources and single estimates for growth rates and control of stationary sources.

For light duty vehicles the new emissions standards are assumed to take effect in 1978 for hydrocarbons and carbon monoxide and in 1979 for nitrogen oxides. The replacement rate for light duty vehicles is assumed to provide for a turnover in vehicles every thirteen years. The assumed distribution of ages of vehicles is presented in Table 2-2.[13] Deterioration of control devices for mobile sources follows the schedule presented in Table 2-3.[14] The deterioration rate is reduced from that presently occurring by assuming that inspection and maintenance plans will be in operation nationwide. The inspection maintenance plans assume that control devices for hydrocarbons and carbon monoxide will be replaced during or after the fifth year of operation. The nitrogen oxide standards assume for the 0.4 and 0.04 standards that inspection and maintenance programs will require the standard to be met in the sixth year of operation. The higher nitrogen oxide emission standards assume that the standard is met only for new cars. California emission standards are sufficiently different for nitrogen oxides that the California cities were modeled separately with separate emission factors. The exhaust emission standards assumed for light duty trucks, and gasoline and diesel powered heavy duty vehicles are presented in Table 2-4. The emission factor ratios for these other mobile sources are summarized in Table 2-1. The emission reduction assumed for these vehicles is less than the emission reduction from light duty vehicles, except for the least stringent scenarios.

Table 2-

ASSUMPTIONS FOR AIR QUALITY PROJECTIONS

Pollutant	Emission Source Category													
	Light Duty Vehicles					Other Mobile Sources					Stationary Sources			
	Emission Standards in Grams Per Mile*	Emission Factor Ratio of Emissions to Base Year**			Growth Rate Percent Compounded	Emission Factor Ratio of Emissions to Base Year				Growth Rate Percent Compounded	Emission Factor Ratio of Emissions to Base Year			Growth Rate Percent Compounded
		1980	1990	1999			1980	1990	1999		1980	1990	1999	
Carbon Monoxide	25.0	.32	.22	.22	1%						.85	.60	.45	3.2%
1970 Emissions = 77.1 grams per mile	15.0+	.32	.13	.13		LDT	.35	.14	.14					
	9.0	.31	.08	.08						1%				
Emission Standards applied to model years 1978 and beyond	3.4++	.29	.04	.03		HDG	.79	.29	.20					
						HDD	1.00	.25	.20					
						Average	.56	.19	.16					
Hydrocarbons/ Oxidants	2.0	.41	.21	.20	3%	LDT	.39	.14	.14		.85	.50	.25	3.2%
	1.5+	.40	.17	.17										
1970 Emissions = 10.3 grams per mile	.9	.38	.12	.12		HDG	.65	.18	.15	3%				
	.4++	.37	.09	.08		HDD	.87	.27	.23					
Emission Standards applied to model years 1978 and beyond	.1	.36	.06	.06		Average	.53	.17	.16					
Nitrogen Oxides	3.1 +	.83	.85	.86	3%	LDT	.87	.52	.52		.90	.70	.40	3.9%
1972 Emissions = 4.1 grams per mile	2.0	.76	.55	.55		HDG	.93	.58	.50	3%				
	1.5	.72	.44	.43										
Emission Standards applied to model year 1979 and beyond	1.0	.69	.30	.29		HDD	1.01	.53	.50					
	.4++	.65	.12	.10		Average	.91	.54	.51					
	.04	.63	.03	.01										

* Current emission standards apply until above changes occur.
**Emission factors are based on deterioration schedule presented in Table 2-2.
+ Present Interim Emission Standard.
\+\+Statutory Emission Standard

TABLE 2-2

DISTRIBUTION OF VEHICLE MILES TRAVELED BY AGE OF AUTOMOBILE

0 to 1 yr.	11.2%
1 to 2 yr.	14.3%
2 to 3 yr.	13.0%
3 to 4 yr.	12.1%
4 to 5 yr.	10.8%
5 to 6 yr.	9.4%
6 to 7 yr.	7.9%
7 to 8 yr.	6.3%
8 to 9 yr.	4.7%
9 to 10 yr.	3.2%
10 to 11 yr.	1.9%
11 to 12 yr.	1.3%
12 to 13 yr.	3.9%
13 yr and over	0 %

Table 2-3

EXHAUST EMISSION FACTORS

grams per mile*

Hydrocarbons**

Age	Exhaust Emission Standards 2.0	1.5	.9	.4	.1
1	1.3	1.0	.6	.3	.08
2	1.6	1.2	.8	.4	.1
3	1.9	1.4	1.0	.5	.13
4	2.1	1.6	1.2	.5	.13
5	2.4	1.8	1.4	.6	.15
6	1.6	1.2	.7	.4	.1
7	1.9	1.4	.8	.5	.13
8	2.3	1.7	1.0	.6	.15
9	2.5	1.9	1.1	.6	.15
10	2.9	2.2	1.3	.7	.18
11	3.2	2.4	1.4	.8	.2
12	3.5	2.6	1.5	.9	.23
13+	3.9	2.9	1.7	1.0	.25

Carbon Monoxide

Age	Exhaust Emission Standards 25	15	9	3.4
1	13.5	8.1	4.9	2.5
2	14.5	8.7	5.3	2.7
3	15.5	9.3	5.7	2.9
4	16.5	9.9	6.1	3.1
5	16.2	9.7	5.9	3.0
6	17.2	10.3	6.3	3.2
7	18.2	10.9	6.7	3.4
8	19.2	11.5	7.1	3.6
9	20.2	12.1	7.5	3.8
10	21.2	12.7	7.9	4.0
11	22.2	13.3	8.3	4.2
12	22.2	13.3	8.3	4.2
13+	22.2	13.3	8.3	4.2

Nitrogen Oxides

Age	Exhaust Emission Standards 3.1	2.0	1.5	1.0	.4	.04
1	3.1	2.0	1.5	1.0	.24	.02
2	3.2	2.1	1.5	1.0	.28	.03
3	3.3	2.1	1.7	1.1	.33	.03
4	3.4	2.2	1.7	1.1	.38	.04
5	3.4	2.2	1.8	1.2	.39	.04
6	3.6	2.3	1.8	1.2	.40	.04
7	3.7	2.3	1.8	1.2	.47	.05
8	3.8	2.4	2.0	1.3	.55	.06
9	3.9	2.5	2.0	1.3	.63	.06
10	4.0	2.5	2.1	1.4	.71	.07
11	4.1	2.6	2.1	1.4	.80	.08
12	4.1	2.6	2.1	1.4	.80	.08
13+	4.1	2.6	2.1	1.4	.80	.08

*The above factors assume inspection and maintenance programs for hydrocarbons and carbon monoxide and for nitrogen oxides at the 0.4 and 0.04 emission standard levels.

**Evaporative emissions for hydrocarbons are to be added to exhaust emission factors.

TABLE 2-4

EXHAUST EMISSION STANDARDS FOR LIGHT-DUTY TRUCKS, AND GASOLINE- AND DIESEL-POWERED HEAVY-DUTY VEHICLES

Pollutant	Standard, gm/mi*			Applicable Model Years
	Light Duty Trucks* (LDT)	Heavy Duty Gasoline** (HGD)	Heavy Duty Diesel** (HDD)	
CO	(***)	242.0	36.0	pre-75
	20.0	164.0	36.0	1975-77
	17.9	143.0	36.0	1978-81
	17.9	48.0	7.2	1982-2000
HC	(***)	29.0	6.3	pre-75
	2.0	13.7	4.6	1975-77
	1.7	3.6	4.6	1978-81
	1.7	3.6	1.3	1982-2000
NO_x	(***)	17.1	22.4	pre-75
	3.1	16.5	25.9	1975-77
	2.3	13.8	20.3	1978-81
	2.3	8.6	11.2	1982-2000

*Emission standards taken from AP-42, Supplement 5, April 1975.

**Emission factors were assumed constant at the level of the standard throughout the life of the vehicle.

***The LDT category was not established until April 1975. Hence pre-75 LDTs were required to meet the same emission standards as light-duty vehicles (automobiles).

For carbon monoxide a growth of one percent compounded annually was selected for all mobile sources. This is a lower growth rate than has been historically observed for metropolitan areas. It was chosen to reflect the fact that carbon monoxide is a localized problem where traffic density is already high and that growth in these areas will not be as great as for the broader metropolitan areas.

For hydrocarbons and nitrogen oxides a growth of three percent compounded annually was selected for all mobile sources. This is also a lower growth than most areas are presently experiencing and is based on the assumption that automobile and truck use in metropolitan areas will not continue to grow at the present rate. The three percent growth was selected because the hydrocarbons and nitrogen oxides are the precursors for oxidant and nitrogen dioxide formation. These pollutants are a problem over wide areas and are not restricted to localized areas of high traffic density.

Stationary source growth rates were estimated from economic indicators for four groupings of sources: electric generation, industrial activities, area sources and other point sources. The sources of carbon monoxide and hydrocarbons are expected to grow at 3.2 percent compounded. Because of the expected increases in the use of coal for fossil fuel electric generation facilities a growth of 3.9 percent was assumed for nitrogen oxide sources.

A single scenario was modeled for stationary sources based on new control technology with successively more stringent controls being applied from 1980 to 1990 and 2000. The assumption about possible control technology was based on a review of existing technologies and technologies which are still under development. For the degree of control assumed, regulations in addition to the present regulations would be necessary to achieve the emission reductions.

While national growth rates were assumed for this study, the contribution of each source category was estimated for each specific area of the country. The contributions for each source category were taken from State Implementation Plans or, if these were not considered adequate, estimated from data within the National Emissions Data System (NEDS). The source contributions by region are presented in Tables 2-5, 2-6, and 2-7.

For estimating the impact on populations outside the specific cities that were modeled, the nation was divided into seven geographic regions which would be expected to have similar air quality for NO_2 and oxidants. The geographic divisions for these regions are given in Table 2-8. The specific emission inventories for each region were obtained from NEDS.[15] The CO concentration is more closely related to population or traffic patterns than to geographic regions, so only an average value for the remainder of the U.S. is presented.

For projecting air quality, the base year concentrations were selected to represent a high year out of a three or four year period. This helps to account for the variability in conditions which affect pollutant levels. For estimating health effects, the base year concentrations were selected to represent an average year over a five year period.

TABLE 2-5

SOURCE CONTRIBUTION OF CARBON MONOXIDE EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary* Sources
004	Birmingham	71	23	6
009	North Alaska	69	21	10
013	Clark-Mohave	73	27	0
015	Phoenix-Tucson	73	26	1
024	Los Angeles	74	25	1
028	Sacramento Valley	72	25	3
029	San Diego	74	26	0
030	San Francisco	73	26	1
031	San Joaquin Valley	72	27	1
036	Denver	73	26	1
042	Hartford-N.Haven	74	26	0
043	NY-NJ-Conn.	74	25	1
045	Philadelphia	72	26	2
047	National Capitol	73	26	1
062	E. Wash.-N. Idaho	73	26	1
067	Chicago	70	26	4
080	Indianapolis	72	26	2
094	Kansas City	72	27	1
115	Baltimore	72	26	2
119	Boston	74	26	0
131	Minn.-St. Paul	73	26	1
158	Central New York	74	25	1
193	Portland	71	25	4
197	S.W. Penna.	72	26	2
220	Wasatch Front	72	26	2
229	Puget Sound	73	26	1
	Other Urban Areas**	60	36	3

*Stationary sources have been adjusted to account for receptor location

**Emissions inventory for other urban areas based on U.S. average emissions

TABLE 2-6

SOURCE CONTRIBUTION OF HYDROCARBON EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary Sources
004	Birmingham	46	21	33
005	Mobile-Pensacola	47	19	34
013	Clark-Mohave	54	15	31
015	Phoenix-Tucson	51	20	29
024	Los Angeles	47	22	31
028	Sacramento Valley	39	18	43
029	San Diego	54	25	21
030	San Francisco	39	18	64
031	San Joaquin	37	17	46
033	S. E. Desert	40	18	42
036	Denver	55	26	19
043	NY-NJ-Conn.	50	23	27
045	Philadelphia	54	25	21
047	National Capitol	55	25	20
079	Cincinnati	48	22	30
067	Chicago	27	13	60
070	St. Louis	30	22	48
106	S. Lou.-S.E. Texas	43	20	37
115	Baltimore	25	13	62
119	Boston	49	23	28
131	Minneapolis-St.Paul	44	26	30
153	El Paso-Las Cruces	59	28	13
160	Genesse-Finger Lakes	57	26	17
173	Dayton	47	22	31
193	Portland	42	19	39
197	S.W. Pennsylvania	48	23	29
214	Corpus-Christi	18	9	73
215	Dallas-Ft.Worth	47	20	33
216	Houston-Galveston	28	13	59
229	Puget Sound	59	27	14
	Geographic Areas			
	Northeast	42	22	36
	East Central	38	25	37
	Mid Central	16	11	73
	Southeast	32	23	44
	West Central	37	37	25
	Southwest	18	18	64
	West	34	25	42

TABLE 2-7

SOURCE CONTRIBUTION OF NITROGEN OXIDE EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary Sources
015	Phoenix-Tucson	40	22	38
024	Los Angeles	46	18	36
030	San Francisco	45	20	35
036	Denver	32	15	53
043	NY-NJ-Conn.	26	10	64
045	Philadelphia	21	11	68
047	National Capitol	31	12	57
067	Chicago	21	12	67
070	St. Louis	12	13	75
115	Baltimore	20	11	69
131	Minneapolis-St. Paul	24	19	57
215	Dallas-Fort Worth	30	24	46
216	Houston	15	15	70
220	Wasatch Front	37	18	45
	Geographic Divisions			
	Northeast	28	17	55
	East Central	18	18	64
	Mid Central	20	17	63
	Southeast	19	19	62
	West Central	26	30	44
	Southwest	19	23	58
	West	29	28	43

Table 2-8

Geographical Divisions for Smaller SMSA Urban Centers and Rural Areas

1. Maine
New Hampshire
Vermont
Massachusetts
Connecticut
New York
New Jersey
Pennsylvania
Delaware
Rhode Island

2. West Virginia
Kentucky
Ohio
Michigan
Indiana

3. Illinois
Missouri
Wisconsin

4. Maryland
District of Columbia
Virginia
North Carolina
South Carolina
Georgia
Florida
Alabama
Mississippi
Tennessee

5. North Dakota
South Dakota
Minnesota
Iowa
Nebraska

6. Arkansas
Texas
Louisiana
Oklahoma
Kansas

7. Montana
Wyoming
Colorado
Utah
New Mexico
Arizona
Idaho
Washington
Oregon
Nevada
California

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3.0 Methodology-Health Consequences

3.1 Health Effects of Automobile Emission Related Air Pollutants

National Ambient Air Quality Standards (NAAQS) for automobile emission related air pollutants were established in 1971. The following sections summarize the effects on human health of carbon monoxide, photochemical oxidants, and nitrogen dioxide.

3.1.1 CARBON MONOXIDE (CO)

The current ambient air quality standard for CO is 10 mg/m^3 for an 8 hour average and 40 mg/m^3 for a one hour average. Carbon monoxide exerts its adverse physiologic influence by interfering with oxygen transport to the cellular level. This occurs due to formation of carboxyhemoglobin (COHb) by combination of inhaled CO with the hemoglobin which ordinarily carries oxygen. Direct interference with cellular respiratory enzymes by CO has been postulated and demonstrated *in vitro* at high concentrations but has not been shown to be clinically significant. Myoglobin also is tightly bound to CO, but no interference with muscle function has been demonstrated. Carbon monoxide interferes with oxygen transport by several related mechanisms. The three most important are: 1) displacement of oxygen from the hemoglobin molecule; 2) change in position and shape of the oxyhemoglobin dissociation curve; and 3) enhancement of existing shunt or ventilation/perfusion imbalance effects. Because carbon monoxide interferes with tissue oxygenation, it is important to consider which tissues may be most susceptible to this effect. Myocardium and nerve tissues have properties with respect to oxygen use and metabolism that make them uniquely susceptible to hypoxia. Energy for cardiac work is derived almost entirely from aerobic glycolysis; there is only limited capacity for anaerobic metabolism.

Utilization of available oxygen by the myocardium is near maximal even at rest. Increased oxygen demands, therefore, can be met only by increasing coronary blood flow. In persons whose capacity to increase blood flow to the heart is limited by disease, even small decrements in available oxygen may result in impaired function. The sensitivity of many central nervous system functions to hypoxia has been repeatedly demonstrated.

3.1.1.1. Effects on Mental Function

Introductory comments in establishing the AAQS for CO did refer specifically to the work of Drs. Beard and Wertheim showing a decrement in human mental performance at very low levels of COHb.(1,2) Thus, the studies of Beard and Wertheim on time interval discrimination are often cited in connection with the carbon monoxide ambient air quality standard as well as occupational standards. More recently Beard and Grandstaff reported impairment of ability to estimate time intervals as well as decrement in several parameters of visual function at COHb levels from 3 percent to 7 percent.(3) Mikulka(4) and Stewart have studied similar aspects of mental function and found decrement only at relatively high levels of COHb. Other investigators are finding interference in human mental performance as well as psychophysiologic alterations with low CO exposure conditions. Bender has found impairment of cognitive function and manual dexterity at 7 percent COHb,(5) Fodor found decreased auditory vigilance at

3-8 percent COHb,(6) and Horvath(7) found decreased visual vigilance at 6.6 percent COHb. Groll-Knapp, *et al* found decreased auditory vigilance at these levels and have also described a negative linear correlation between CO level and the amplitude of aurally induced EEG potentials.(8)

The interpretation of all these studies is controversial, but there seems to be enough consistency in them to suspect a real effect of relatively low CO concentrations on certain aspects of vigilance (signal detection) and visual performance.

3.1.1.2 Possible Effects of Carbon Monoxide on the Normal Circulation

Increased oxygen debt and decreased maximal oxygen uptake following CO exposure in normal exercising subjects have been accepted as evidence of effects on normal cardiovascular function. These observations have been substantiated by the more recent work of Vogel, *et al*(9) and Anderson, *et al*.(10) Vogel's group found maximal oxygen uptake reduced by 24 percent and heart rate increased at all corresponding levels of exercise in normal men after attaining 20 percent COHb. Anderson also found increased heart rate at all levels of exercise in normal men at 5-7 percent COHb and in addition found significant worsening of mechanical myocardial function as indirectly determined by systolic time intervals.

3.1.1.3 Hypothetical Effects of Carbon Monoxide on Susceptible Persons

Astrup(11) has found a negative correlation between COHb level in pregnant women and subsequent birth weight in their offspring. Other hypothetical effects include those of anemia and increased endogenous CO production from hemolysis. As an example, hemolytic anemia leading to a ten fold increase in endogenous CO production and a hemoglobin level of 7 grams percent in an individual exposed to 20 ppm CO for 4 hours would result in about 4 percent COHb rather than 1.5 percent COHb in a normal individual. These hypothetical effects have not been experimentally confirmed.

3.1.1.4. A Possible Effect of Increased Ambient Levels of Carbon Monoxide in Coronary Vascular Disease

Interpretation of several epidemiological studies of CO effects on cardiovascular disease remains controversial. Cohen, *et al*(12) related survival from myocardial infarction to ambient CO levels. A study by Wald, *et al*(13) found the incidence of arteriosclerotic heart disease to be more closely correlated with COHb levels that with the number of cigarettes smoked. A person with 5 percent COHb had 21 times the risk of arteriosclerotic heart disease than one with 3 percent COHb. Aronow, *et al*(14) found significant changes in electrocardiograms of men with coronary artery disease who were exposed to CO in freeway traffic. Anderson, *et al*(15) found very similar changes in men with angina pectoris exposed to low level CO by face mask. In addition they found a decrease in time to onset of angina during exercise at 2.9 percent COHb and 4-5 percent COHb. Duration of the anginal pain was prolonged at 4.5 percent COHb but not at the lower level.

Anderson's study has been substantiated by Aronow, *et al*.(16) In addition, Aronow and his colleagues found decreased exercise tolerance in men with intermittent claudication at COHb levels of about 3 percent.(17) Thus the work of Anderson and Aronow describe cardiovascular effects in susceptible persons at COHb levels only twice that provided for by the current AAQS.

Most recently Haak and Becker(18) have described a dose-response relationship for CO-induced myocardial ischemia in dogs. These data provide, for the first time, a reasonable estimation of mortality that can be associated with ambient CO exposure.(19)

3.1.1.

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*All manuscripts referred to as "unpublished data" may be obtained upon request to the:

Freedom of Information Office (A101)
Environmental Protection Agency
Waterside Mall Building
4th and M Streets, S.W.
Washington, D. C. 20460

3.1.2. Photochemical Oxidants

The present U.S. National Primary Standard for photochemical oxidants is 160 μg/m^3 maximum one hour concentration not to be exceeded more than once per year. Compliance with this Ambient Air Quality Standard (AAQS) is sought by emission control of hydrocarbons which are oxidant precursors, rather than control of oxidants themselves.

The original evidence for the ambient standard in humans was based on increased illness including aggravation of asthma and chronic lung disease, irritation of the respiratory tract in healthy adults, decreased visual acuity, increased eye irritation, and changes in heart and lung function in healthy subjects. These data were thoroughly and carefully reviewed in the original photochemical oxidant criteria document.(1)

Since promulgation of the standard, much new information on the health effects of oxidants has been obtained. Bates, *et al* observed substernal soreness, cough, and some pharyngitis and dyspnea coupled with decreased pulmonary function among healthy volunteers exposed experimentally to 1500 μg/m^3 of ozone for two hours and lightly exercising.(2) Hazucha, *et al*(3) observed similar effects in volunteers exposed to either 1500 μg/m^3 or 740 μg/m^3 of ozone for two hours. Bates(4) reported a marked decrease in pulmonary function among healthy subjects performing light exercise and exposed simultaneously to 740 μg/m^3 of ozone and 1000 μg/m^3 of sulfur dioxide for two hours. This deleterious effect may be synergistic and a deleterious synergism of O_3 and SO_2 upon plants has been well described in the original criteria document.(1)

Hammer, *et al*(5) studied student nurses in Los Angeles prospectively by means of daily symptom diaries during the three years of their training. Headache, eye discomfort, cough and chest discomfort were all found to be related to ambient daily photochemical oxidant exposure.

Two recent reports summarize new studies of experimental ozone exposure. Kerr, *et al*(8) studied twenty lightly exercising subjects exposed to 1000 μg/m³ ozone for six hours. Symptoms most commonly noted were dry cough and chest discomfort; these symptoms were experienced more frequently by nonsmokers. Significant changes were found in a variety of pulmonary function tests. In addition, nonsmokers exhibited a significant decrease in dynamic compliance during exposure. In general, there was a relationship between experiencing symptoms and alterations in pulmonary function among the study subjects.

Hackney(9) exposed adult male volunteers doing intermittent light exercise to 740 μg/m³ or 1000 μg/m³ of ozone for two hours. These subjects not only developed measurable physiological and biochemical changes, but felt physically ill and were unable to perform their normal jobs during exposure and for several hours afterward. All subjects developed biochemical changes and the least sensitive subjects developed no respiratory symptoms or physiological changes after five hour exposures to 1000 μg/m³ ozone on two successive days. The most sensitive subjects experienced respiratory symptoms after a single two hour exposure to 740 ug/m³ of ozone. The more reactive subjects were generally those with history of asthma, allergy, or previous adverse symptom reactions to smog exposure.

These and studies currently being conducted by EPA were recently reviewed.(10) These studies corroborate the findings of previous workers and extend them. Observations of altered resistance to infection in animals(11-17) have been substantiated by the finding of altered immune status of human subjects experimentally exposed to ozone (800 μg/m³ for 4 hours).

Photochemical oxidants, ozone in particular, are primary irritants causing aggravation of asthma, impairment of athletic performance, severe respiratory tract irritation and altered pulmonary function in healthy adults under experimental, occupational, and ambient exposure conditions. In animals, ozone alters host defenses against infection, causes various structural changes to the lung and hematopoietic tissue, and produces chromosome breaks in peripheral lymphocytes even at ambient concentrations.

3.1.2.
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3.1.3. Nitrogen Dioxide(NO_2)

The current primary and secondary AAQS for NO_2 is 100 ug/m^3 (0.05 ppm) annual arithmetic mean. The current AAQS was based largely on a set of studies conducted in Chattanooga, Tenn. These, often referred to as the Chattanooga School Children Studies (1,2,3) afforded an opportunity to assess the influence of NO_2 on acute respiratory disease experience in populations. A total of 871 families with 4043 individuals participated in disease surveillance between November 1968 and April 1969. Average bi-weekly respiratory illness rates were significantly higher for the children residing in the neighborhood with highest NO_2 concentrations.

These same neighborhoods were surveyed in 1970 with regard to the frequency of more severe acute lower respiratory disease among first and second grade elementary school children and infants born between 1966 and 1968. Information on the occurrence and frequency of bronchitis, croup and pneumonia occurring between July 1966 and June 1969 in 3217 children was obtained retrospectively, and hospital records were searched to validate a sample of questionnaire responses. Bronchitis rates correspond to the area gradient in nitrogen dioxide exposure among the larger population of school children who had lived at their current residence for three or more years; these area differences were statistically significant ($p < 0.01$). Among school children who had lived at their current residence for two years or less, bronchitis rates did not follow the nitrogen dioxide exposure gradient, although bronchitis rates were lowest in the low nitrogen dioxide neighborhood. These area differences were also statistically significant ($p < 0.02$). Among school children in the one year exposure category and among all infants, area differences in lower respiratory disease rates were not statistically significant, although the general pattern of more respiratory disease in the high nitrogen dioxide area when compared with the low nitrogen dioxide neighborhood was maintained.

Lung function of seven to eight year old school children was assessed in relationship to community nitrogen dioxide exposures. Weekly determinations of three-quarter second forced expiratory volumes ($FEV_{0.75}$) were obtained during two months of the school year from 306 children living in a relatively high nitrogen dioxide exposure neighborhood, from 264 children living in an intermediate nitrogen dioxide exposure area and from 225 children from a low nitrogen dioxide exposure area. $FEV_{0.75}$ values of children in the high nitrogen dioxide area were significantly ($p < 0.05$) lower than values for children in the other study areas. These differences, however, were small in magnitude and were not consistent during the two months of testing. Lung function of children in the intermediate and low nitrogen dioxide exposure areas were not significantly different. The diminished lung function of children from the high nitrogen dioxide area was associated with nitrogen dioxide exposures of 150 to 282 $\mu g/m^3$ (0.08 to 0.15 ppm) annual arithmetic mean as determined by the continuous Saltzman method. Alternatively, the lower values for lung function may have been attributable to repeated peak nitrogen dioxide exposures as determined by the 90th percentile of frequency distribution of hourly values over one year. In this case, diminished lung function would be attributed to repeated 2-3 hour daily peak nitrogen dioxide concentrations of 282 to 940 μg/m^3 (0.15 to 0.50 ppm). The strength of the association in the Chattanooga Study between diminished lung function and nitrogen dioxide exposure is relatively weak owing to lack of consistency of the association over time and the absence of a clear dose-response relationship.

Since the initial population studies in Chattanooga, a vigorous pollution control program instituted by the Department of Defense and a decrease in TNT production has been accompanied by a decrease in NO_2 emissions as evidenced by a decrease in the annual average levels of NO_2 in the most exposed study neighborhoods. Despite these lower annual NO_2 levels, the population living in the community with the previously high annual average exposure to NO_2 continued to experience intermittent short-term exposure to NO_2 as measured by the 90th percentile of daily hourly NO_2 concentrations.

Subsequent studies were conducted in Chattanooga encompassing the period from 1968 to 1973. Unfortunately the Jacobs-Hochheiser method of measuring NO_2 was used in these studies from 1968 to 1972 when the chemiluminescent method was introduced thus necessitating the substitution of continuous Saltzman data for the year 1968 and additional Saltzman data for specific stations in 1970 and 1971.

These increases in human acute respiratory disease rates associated with NO_2 exposure are consistent with results of laboratory animal experiments using much higher doses. Several studies in animals show relationships between nitrogen dioxide exposure and impaired resistance to respiratory pathogens. The mortality of mice challenged with inhalation of Klebsiella pneumoniae and exposed to 940 $\mu g/m^3$ (0.5 ppm) nitrogen dioxide for 6, 18, or 24 hours per day for three months was significantly greater than that for animals similarly challenged but allowed to breathe clean air.(6,7) Many mechanisms have been studies which may account for the observed increase in acute respiratory disease mortality with experimental exposures. They include changes in pulmonary clearance of viable bacteria,(6-10) antibody titres,(11) interferon production,(12,13) and bactericidal activity of lung tissue.(14)

Thus animal experiments as well as human population studies affirm a relationship between nitrogen dioxide exposure and impairment of resistance to human respiratory pathogens. The question of the dose rate (repeated peak levels vs. long term average concentration) that was most responsible for the health effect cannot be definitively answered. Evidence from animal studies would suggest that repeated short term exposures of 6 hours per day for 3 months are sufficient to interfere with natural body defense mechanisms. Prolongation of exposures at the same nitrogen dioxide concentration did not cause a further excess in mortality of exposed animals.(6) On the other hand, cumulative exposures to nitrogen dioxide over the lifetime of animals resulted in loss of cilia, hypertrophy and inflammation of terminal bronchiolar epithelium; these tissue changes are likely to enhance the body's susceptibility to infection. At the present time, therefore, further experimental evidence is needed to determine the most appropriate averaging time for associating nitrogen dioxide exposure with increased susceptibility of humans to infection.

3.1.3.

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3.2 METHODOLOGY FOR PROJECTING HUMAN HEALTH CONSEQUENCES

This section describes the methodology used to estimate future national human health consequences which may be expected to result from the implementation of alternative levels of mobile source emission control.

To develop these estimates, per year human health consequences were obtained for each of three future years (1980, 1990, 2000) by aggregating similar estimates made at both the Air Quality Control Region (AQCR) level and the multi-state geographical level. From these per year national figures, estimates for the twenty-year, 1980-2000 period, were obtained by numerically integrating (by Simpson's rule) the average yearly health effects for 1980, 1990, and 2000. To estimate the per year human health consequences for each of the three future years, three basic types of data were used: (1) pollutant specific damage functions relating per year health consequences to incremental levels of air pollutant exposure using a total population basis; (2) air pollutant concentration projections at both the AQCR level and multi-state geographical level; (3) and projected total populations for each AQCR and each multi-state geographical division considered.

Each of these basic types of data differs slightly for the three automotive related pollutants considered; carbon monoxide, nitrogen dioxide, and photochemical oxidants. Therefore, in the following pages these data are discussed on an individual pollutant basis.

3.2.1. CARBON MONOXIDE

The damage function obtained from EPA's Office of Research and Development related excess cardiac deaths and excess person hours of disability to incremental ambient levels of carbon monoxide exposure. This function is presented in Table 3-1. The ambient levels were expressed as the annual geometric mean of the maximum daily eight-hour average for each of the three standard geometric deviations. The annual geometric means varied from 2,000 to 10,000 $\mu g/m^3$, in increments of 2,000 $\mu g/m^3$, and the three standard geometric deviations provided for each mean were 1.3, 1.5, and 1.7. The excess cardiac deaths were defined as a per year rate per million total population. The excess person hours of disability were similarly defined as excess person hours of disability per million total population per year. Both were provided for each of the five incremental means and the three standard geometric deviations. Thus, the damage function was essentially a matrix containing thirty estimates of damage to human health.

This damage function was applied to carbon monoxide concentration projections developed for each of the three future years in twenty-six AQCR's and one hypothetical region. Because elevated carbon monoxide concentrations are a problem in other urban centers, this hypothetical region was used as a surrogate for the remainder of the urban - Standard Metropolitan Statistical Areas (SMSA) - U. S. population not residing in the twenty-six AQCR's. The 1970 base year concentration for this region was assumed to be twice the National Ambient Air Quality Standard.

TABLE 3-1

DAMAGE FUNCTION FOR EXPOSURE TO CARBON MONOXIDE

Carbon Monoxide Mean* µg/m3	Standard Geometric Deviation of Carbon Monoxide Concentration	Health Consequences Per Million Total Population Per Year	
		Excess Deaths	Excess Person-Hours of Disability
2000	1.3	.00	0
	1.5	.00	0
	1.7	.00	52
4000	1.3	.00	14
	1.5	.00	688
	1.7	.18	2738
6000	1.3	.00	1572
	1.5	.33	6397
	1.7	1.47	12777
8000	1.3	.23	10912
	1.5	1.89	20302
	1.7	4.74	30285
10000	1.3	1.68	30064
	1.5	5.49	40954
	1.7	10.16	53049

*Annual geometric mean of the daily maximum 8-hour average concentration.

The annual maximum eight-hour concentration was projected for the three future years for each of these twenty-seven areas. From this projection, the annual geometric mean of the daily maximum eight-hour concentration was obtained by assuming a lognormal distribution and applying the following relationship:

$$C_{\substack{\text{Geometric}\\ \text{Mean}}} = \frac{C_{\text{8-hour maximum}}}{(\text{Standard Geometric Deviation})^{2.94}}$$

The standard geometric deviation for each of the twenty-seven areas was chosen as 1.5 for each future year.

Total population projections were obtained using only SMSA population projections obtained from OBERS - 1972 Series E SMSA projections. The hypothetical region's population was assumed to be the remainder of the U.S. living in SMSA's outside of the SMSA's incorporated in the twenty-six AQCR's. These population projections are presented in Table 3-2.

These total population projections were used as the basis for estimating the number of persons affected by elevated ambient carbon monoxide levels. The number of persons exposed to maximum daily eight-hour concentrations is not known. Elevated carbon monoxide levels are understood to be more confined to a localized setting characterized by high density automobile traffic rather than over an entire urban area. Furthermore, the non-smoking population is understood to be more directly impacted by elevated ambient carbon monoxide than the smoking population, since cigarette smoking probably causes significantly more inhalation of carbon monoxide than either observed or predicted ambient levels. For these reasons, total population projections are believed

Table 3-2

POPULATION PROJECTIONS
USED IN DETERMINING HEALTH IMPACT OF ALTERNATIVE CO SENARIOS

Population in Thousands

REGION		1980	1990	2000
004	Birmingham	817	883	916
009	North Alaska	85	90	94
013	Clark-Mohave	483	648	818
015	Phoenix-Tucson	1716	2129	2447
024	Los Angeles	7708	8481	9116
028	Sacramento Valley	896	1006	1094
029	San Diego	1516	1777	1976
030	San Francisco	3446	3839	4155
031	San Joaquin Valley	737	772	789
036	Denver	1553	1784	1981
042	Hartford-N.Haven	1724	1908	2073
043	NY-NJ-Conn.	12258	13326	14323
045	Philadelphia	5278	5679	6016
047	National Capitol	3474	4383	5190
062	E. Wash.-N.Idaho	309	319	326
067	Chicago	7655	8335	8935
080	Indianapolis	1247	1407	1540
094	Kansas City	1450	1635	1793
115	Baltimore	2170	2359	2488
119	Boston	4113	4568	4996
131	Minn.-St. Paul	2095	2456	2760
158	Central New York	1035	1095	1146
193	Portland	1147	1288	1391
197	S.W. Penna.	2461	2510	2539
220	Wasatch Front	616	717	791
229	Puget Sound	1908	2101	2247
999	Other Urban Areas	95946	108352	118477
TOTAL		163843	183847	200417

to overstate the number of persons impacted by ambient elevated eight-hour carbon monoxide concentrations. Therefore, one-tenth of the total population projections was used to provide an estimate of the number of persons impacted by ambient carbon monoxide. The other ninety-percent of the population are assumed to not be affected by carbon monoxide concentrations.

Since the carbon monoxide concentrations of the damage function were discrete points while the projections were continuous, very seldom did the projections correspond to points on the damage function. A standard polynomial approximation routine was used in applying the damage function to the carbon monoxide projections. The Lagrange Interpolation Polynomial of Degree Three was used, because it would provide smoothing to the large differences in neighboring points of the damage function.

3.2.2. PHOTOCHEMICAL OXIDANTS

The damage function obtained from EPA's Office of Research and Development related six categories of human health consequences to ambient incremental levels of photochemical oxidant exposure (see Table 3-3). The six health consequences were: excess aggravation of heart and lung disease in elderly patients; excess aggravation of asthma; excess eye discomfort; excess cough; excess chest discomfort; and excess headache. The ambient levels of photochemical oxidants were expressed as the annual geometric mean of daily maximum one-hour averages at each of five standard geometric deviations: 1.8, 2.0, 2.2, 2.4, and 2.6. The annual geometric means varied from 40 to 200 ($\mu g/m^3$) in increments of 20 ($\mu g/m^3$) with an additional mean of 250 ($\mu g/m^3$). The six health consequences were defined as per year rate of excess person days of the health consequence per million total population fo- each of the ten incremental means and the five standard geometric deviations. Thus, the

Table 3-3

DAMAGE FUNCTION FOR EXPOSURE TO PHOTOCHEMICAL OXIDANTS

Oxidants Mean* µg/m³	SGD of Oxidant Concentration	Health Consequences Excess Person Days Per Million Total Population Per Year					
		Aggravation of Heart and Lung Disease in Elderly Patients	Aggravation of Asthma	Eye Discomfort	Cough	Chest Discomfort	Headache
40	1.8	0	0	0	0	0	2284
	2.0	0	0	902	0	0	4902
	2.2	26	2	3749	403	0	8362
	2.4	163	16	9256	2559	246	12504
	2.6	443	44	17796	6943	680	17232
60	1.8	0	0	1723	0	0	10151
	2.0	82	8	7390	1293	110	16385
	2.2	355	35	18216	5563	524	23396
	2.4	891	89	34463	13966	1406	31071
	2.6	1740	174	55869	27267	2811	39353
80	1.8	69	6	8377	1076	65	24114
	2.0	405	40	23607	6342	601	33695
	2.2	1146	111	46926	17948	1787	43943
	2.4	2351	235	77516	36834	3781	54846
	2.6	4021	402	114547	63009	6602	66403
100	1.8	295	29	23174	4616	414	42621
	2.0	1100	110	51962	17233	1683	55144
	2.2	2538	253	90599	35766	4038	68190
	2.4	4608	460	137200	72192	7513	81991
	2.6	7267	726	190904	113843	12050	96574
120	1.8	781	78	48362	12238	1149	64626
	2.0	2270	227	93131	35565	3540	79399
	2.2	4588	458	148113	71881	7394	94909
	2.4	7661	766	211432	120016	12613	111364
	2.6	11404	1140	281966	170661	19054	128784
140	1.8	1621	162	84974	25334	2438	83019
	2.0	3979	397	146887	62336	6291	105536
	2.2	7306	730	218298	114463	11894	123295
	2.4	11465	11465	298093	179622	19019	142246
	2.6	16344	1634	385175	256061	27474	162381
160	1.8	2890	289	133056	45280	4422	114645
	2.0	6258	625	211642	98042	10005	132942
	2.2	10676	1067	299475	167254	17516	152826
	2.4	15964	1596	395270	250099	26643	174178
	2.6	22000	2199	498420	344659	37161	196951
180	1.8	4339	463	192031	72685	7197	141210
	2.0	9110	911	286785	142725	14697	161216
	2.2	14661	1466	390139	229629	24214	183162
	2.4	21093	2109	501312	330459	35394	206858
	2.6	28286	2828	620002	443153	47976	232222
200	1.8	6897	689	260970	103053	10824	168393
	2.0	12523	1252	370876	196191	20359	190093
	2.2	19219	1921	488936	301096	31922	214070
	2.4	26791	2679	614833	419729	45139	240081
	2.6	35131	3513	748541	550380	59796	265310
250	1.8	14790	1478	469904	231703	23734	237873
	2.0	23319	2331	612829	365332	33489	263683
	2.2	32817	3281	764183	514134	55119	292933
	2.4	43155	4315	924311	676096	73343	324693
	2.6	54272	5427	1093539	850262	93025	358883

*Annual geometric mean of the daily maximum 1-hour concentration damage function was essentially a matrix containing three hundred estimates of human health consequences resulting from photochemical oxidant exposure.

These damage functions assumed thresholds for onset of each consequence as detailed in Table 3-4. The studies used to develop these threshold estimates involved a relatively healthy segment of the population. As a result, the thresholds for some effects are high relative to the photochemical oxidant national ambient air quality standard, which has been set to protect all segments of the population. Because those more susceptible individuals are likely to be a small percentage of total population and for ease in calculations, effects below the listed thresholds have not been estimated. Since these thresholds were used to develop national projections, it is expected that the resulting projections would provide modest estimates of the health effects of photochemical oxidant exposure.

This damage function was applied to photochemical oxidant projections developed for each of the three future years in thirty air quality control regions and seven multistate geographical divisions. The population projections are presented in Table 3-5.

Both the geometric mean of the daily maximum one-hour concentration and the second highest one-hour concentration were projected. The projected standard geometric deviation was determined by assuming a lognormal distribution of the ratio of the second highest hour to the geometric mean of the daily maximum one-hour concentration and by applying the formula:

$$\text{standard geometric deviation} = \left(\frac{C_{\text{2nd max. hour}}}{C_{\text{mean daily max. hour}}}\right)^{1/2.62}$$

TABLE 3-4

PHOTOCHEMICAL OXIDANT EXPOSURE CONCENTRATION USED TO ESTIMATE THRESHOLD OF HEALTH CONSEQUENCE

Adverse Health Consequence	Threshold Concentration (for one hour or more in $\mu g/m^3$)
Aggravation of Heart and Lung Disease in Elderly Patients	400
Aggravation of Asthma	400
Eye Discomfort	260
Cough	400
Chest Discomfort	420
Headache	100

Table 3-5

POPULATION PROJECTIONS
USED IN DETERMINING HEALTH IMPACT OF ALTERNATIVE OX SENARIOS

Population in Thousands

REGION	1980	1990	2000
004 Birmingham	817	883	916
005 Mobile-Pensacola	659	728	768
013 Clark-Mohave	483	648	818
015 Phoenix-Tucson	1716	2129	2447
024 Los Angeles	7708	8481	9116
028 Sacramento Valley	896	1006	1094
029 San Diego	1616	1777	1976
030 San Francisco	3446	3839	4155
031 San Joaquin	737	772	789
033 S. E. Desert	84	95	105
036 Denver	1553	1784	1981
043 Ny-NJ-Conn.	12258	13326	14323
045 Philadelphia	5278	5679	6016
047 National Capitol	3474	4383	5190
067 Chicago	7655	8335	8935
070 St. Louis	2562	2717	2825
079 Cincinnati	1499	1636	1738
106 St. Louis-S.E. Texas	1769	1939	2050
115 Baltimore	2170	2359	2488
119 Boston	4113	4568	4996
131 Minn.-St. Paul	2095	2456	2760
153 El Paso-Las Cruces	542	589	638
160 Genesse-Finger Lakes	1059	1247	1413
173 Dayton	946	1058	1153
193 Portland	199	213	225
197 S.W. Pennsylvania	2461	2510	2539
214 Corpus-Christi	297	318	330
215 Dallas-Ft.Worth	2669	3166	3589
216 Houston-Galveston	2597	3110	3517
229 Puget Sound	1908	2101	2247
991 Northeast	20428	22588	24331
992 East Central	21614	23688	25353
993 Mid Central	5430	5927	6348
994 Southeast	20836	25143	28961
995 West Central	2263	2429	2618
996 Southwest	7493	8284	8728
997 West	9665	10861	11775

For the seven geographical divisions, the median for available data of both geometric mean and the second highest one-hour concentration were chosen as the base year concentration estimates.

As with population estimates used for projecting health consequences of carbon monoxide exposure, the population projections of those AQCR's individually modeled were excluded from the geographical division population estimates.

Since the pollutant concentration levels of the photochemical oxidant damage function were discrete points while the projected levels were continuous, very seldom did the projections correspond to points on the damage function matrix. Therefore, the damage function relation was calculated on a continuous basis for the projected air quality of each AQCR. This calculation provides a more precise estimate of the health consequences than a table look-up procedure would provide.

3.2.3. NITROGEN DIOXIDE

The damage function obtained from EPA's Office of Research and Development related excess attacks of lower respiratory disease in children and corresponding excess days of restricted activity to incremental ambient levels of nitrogen dioxide exposure. This function is presented in Table 3-6. These levels were expressed as annual arithmetic averages varying from 50 to 200 $\mu g/m^3$ in increments of 25 $\mu g/m^3$. The excess attacks of lower respiratory disease and associated excess days of restricted activity in children were defined as per year

TABLE 3-6

DAMAGE FUNCTION FOR EXPOSURE TO NITROGEN DIOXIDE

Nitrogen Dioxide Annual Average μ/gm^3	Baseline Incidence Per Child Per Year	Health Consequences Per Million Total Population Per Year	
		Excess Attacks of Lower Respiratory Disease in Children	Excess Days of Restricted Activity from Lower Respiratory Disease in Children
50	0.5	0	0
	1.0	0	0
	1.5	0	0
	2.0	0	0
75	0.5	5,875	15,628
	1.0	11,750	31,255
	1.5	17,625	46,883
	2.0	23,500	62,510
100	0.5	11,750	31,255
	1.0	23,500	62,510
	1.5	35,250	93,765
	2.0	47,000	125,020
125	0.5	17,625	46,883
	1.0	32,250	85,785
	1.5	52,875	140,648
	2.0	70,500	187,530
150	0.5	23,500	62,510
	1.0	47,000	125,020
	1.5	70,500	187,530
	2.0	94,000	250,040
175	0.5	29,375	78,138
	1.0	58,750	156,275
	1.5	88,125	234,413
	2.0	117,500	312,550
200	0.5	35,250	93,765
	1.0	70,500	187,530
	1.5	105,750	281,295
	2.0	141,000	375,060

per million total population for each of the eight incremental annual arithmetic averages of nitrogen dioxide.

These estimates were developed for each of four assumptions of background acute lower respiratory disease incidence. These four background incidences were defined as the per child per year rate of attacks of acute lower respiratory disease which might occur without elevated nitrogen dioxide levels. Ranging from 0.5 to 2.0 in increments of 0.5, the 0.5 background assumption was chosen because it would provide some measure of the benefits of future disease prevention technology. Thus, the damage function matrix consisted of estimates of two health consequences at each of seven annual arithmetic averages of nitrogen dioxide exposure and four background incidence rates or a total of fifty-six health consequences estimates.

The damage function shows a simple linear relationship between lower respiratory disease attacks and days of restricted activity. The latter is likely dependent in some positive degree on the former. The constant estimate of 2.66 days of restricted activity for each occurrence of lower respiratory disease was obtained from National Health Survey Statistics.

The damage function clearly shows excess lower respiratory diseases occurring at levels below the current annual standard for nitrogen dioxide of 100 μg/m^3 as an annual arithmetic average. While the annual standard is felt to be adequate on an annual basis, that human health consequences have been calculated at lower levels suggests this standard may not be sufficient. Recent data obtained from laboratory studies suggest human health consequences may occur under peak exposure conditions for short durations. These peak exposure effects are probably reflected in this damage function. Likewise, it should be noted that there is a paucity of data available to describe any dose response estimates for NO_2. Those presented here are from a single study and subject to refinement as the data base is improved.

This damage function was applied to projections of annual nitrogen dioxide arithmetic averages developed for each of the three future years in each of fourteen AQCR's and seven multistate geographical divisions of U. S. urban (SMSA) population centers. The seven multistate geographical divisions of urban population centers were chosen because elevated nitrogen dioxide concentrations are expected to be a problem of increasing magnitude in future years. For these seven divisions, the median annual arithmetic average concentration for the available nitrogen dioxide data was chosen as the base year concentration estimate.

As with population estimates used for projecting health consequences of carbon monoxide exposure, only urban centers of greater than 50,000 inhabitants within the AQCR's and geographical divisions were used to estimate total population. The population estimates for the geographical divisions were defined as the sum of those urban centers within the geographical division not including the fourteen AQCR's individually considered. The population projections are presented in Table 3.7.

The nitrogen dioxide damage function is discrete while the concentration projections are continuous. Therefore, when a projected concentration fell between two damage function concentrations the lower damage function estimate was used. Implicitly, this method results in a more conservative estimate than a continuous calculation or interpolation method would provide.

Table 3-7

POPULATION PROJECTIONS
USED IN DETERMINING HEALTH IMPACT OF ALTERNATIVE NO_x SENARIOS
Population in Thousands

REGION		1980	1990	2000
015	Phoenix-Tucson	1716	2129	2447
024	Los Angeles	7708	8481	9116
030	San Francisco	3446	3839	4155
036	Denver	1553	1784	1981
043	NY-NJ-Conn.	12258	13326	14323
045	Philadelphia	5278	5679	6016
047	National Capitol	3474	4383	5190
067	Chicago	7655	8335	8935
070	St. Louis	2562	2717	2825
115	Baltimore	2170	2359	2488
131	Minn.-St. Paul	2095	2456	2760
215	Dallas-Ft. Worth	2669	3166	3589
216	Houston-Galveston	2597	3110	3517
220	Wasatch Front	616	717	791
991	Northeast	28061	30913	33273
992	East Central	24059	26382	28244
993	Mid Central	5430	5927	6348
994	Southeast	22312	26754	30645
995	West Central	2263	2429	2618
996	Southwest	10101	11130	11746
997	West	15820	17831	19404

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4.0 PROJECTIONS

4.1 STATIONARY AND MOBILE SOURCE CONTRIBUTIONS TO CURRENT AMBIENT AIR QUALITY

On May 30, 1975, the Administrator of the Environmental Protection Agency (EPA) announced that although significant progress had been made in improving air quality since 1970, a number of cities would not attain the national standards by deadlines mandated in the Clean Air Act Amendment. Included in this non-attainment status are a number of cities experiencing problems with one or more of the automotive related pollutants - carbon monoxide, hydrocarbons, and oxides of nitrogen.

Air quality monitoring data reveals that at least 65 Air Quality Control Regions (AQCR's) experienced violations of the 8-hour (10 milligrams per cubic meter(mg/m^3)) carbon monoxide ambient standard during 1973. The same data indicated that another four AQCR's experienced maximum concentrations above the CO standard; however, because the second highest concentration occurred on the same day as the maximum value, a technical problem with the data (in its present form) precludes positively stating that violations actually occurred in these four AQCR's*. Available 1974 air quality monitoring data indicate that 43 of the above AQCR's experienced violations in 1974, and another 7 had maximum concentrations above the CO standard. The 1974 data are incomplete at this time, and in general only represent the first six months of the year. Table 4-1 contains a list of the AQCR's cited above, along with second high concentrations (or maximum where noted) experienced

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* The national standard may not be exceeded more than once per year (i.e., a single reading above the standard is not considered a violation).

Table 4-1

AQCR's Experiencing Violations of The CO Eight-Hour NAAQS in 1973/74

AQCR	1973 As of 4/7/75 2nd High mg/m^3	1974 Partial Year 2nd High mg/m^3
004 Birmingham	18.8	9.5
008 Anchorage	10.7	18.0
009 Fairbanks	30.4	30.5
013 Las Vegas	16.4	13.1
015 Phoenix	25.7	21.6
018 Memphis	19.3	12.6*
024 Los Angeles	33.3	27.5
028 Sacramento	11.6*	13.1
029 San Diego	13.4	3.9
030 San Francisco	18.5	12.4
031 San Joaquin Valley	13.4	8.9
032 S. Cent. Coast, Cal.	12.8	6.8
033 S.E. Desert, Cal.	10.2	7.0
036 Denver	33.8	24.3
042 Hartford-N.H.	25.5	27.7
043 Metro N.Y.	56.8	44.3
045 Philadelphia	30.6	20.9
047 Washington, D.C.	20.3	12.9
056 Atlanta	18.1	13.9
060 Hawaii	12.2	-
062 Spokane	17.0	30.6
067 Metro Chicago	22.2	19.7
070 St. Louis	20.8	18.1
072 Paducah, Ky.	17.2	7.1
077 Owensboro, Ky.	22.6	9.8
078 Louisville, Ky.	19.1	14.0
085 Omaha, Neb.	10.7	10.3
092 Des Moines	16.6	17.4
094 Kansas City	13.5	11.9
095 Topeka	10.6	11.1*
099 Wichita	17.5	21.0
102 Lexington	-	10.9
103 Ashland	14.7	10.3*
106 New Orleans	13.4	11.4
113 Cumberland	14.7	-
115 Baltimore	15.6	-
118 Cent. Massachusetts	14.9	13.2
119 Boston	19.5	19.7
120 Providence	15.6	19.2
121 Merrimack Val., N.H.	14.4	12.4*
124 Toledo	12.5	13.1*
131 Minn. St. Paul	11.5	11.2
145 Lincoln	17.2	13.4
148 Reno	17.2	-
150 New Jersey	18.9	14.4
151 Scranton	11.5	9.7
152 Albuquerque	26.9	19.4
153 El Paso	18.5	15.0
157 Upper Rio Grande	20.6	15.3
158 Syracuse	14.1	9.0
159 Champlain Val., N.Y.	10.1	-
160 Rochester	11.1*	8.2
161 Schenectady	15.1	6.4
162 Buffalo	11.2	10.5*
167 Charlotte, N.C.	18.0	27.2
173 Dayton	35.7	-
174 Cleveland	19.8	-
176 Columbus	10.9	14.9
184 Oklahoma City	22.9	11.0
186 Tulsa	11.8	16.5
193 Portland, Oregon	24.9	25.5
197 Pittsburgh	24.4	-
208 Mid-Tennessee	15.9	23.2
216 Houston	-	13.3
220 Salt Lake City	25.7	12.6
223 Hampton Roads	13.0	10.9
225 Richmond	14.8*	12.6*
229 Puget Sound	24.1	23.1
239 Milwaukee	12.2*	10.3

* Maximum values.

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in 1973. Also shown are similar results based upon incomplete data for the year 1974. It can be seen from Table 4-1 that many of the large urban areas of the country experienced problems with CO concentrations during 1973 and 1974.

While available air quality monitoring data indicate CO problems in many large urban areas, it should be pointed out that no monitoring data are available for many areas of the country. Therefore, it cannot be concluded that CO problems are confined solely to those areas shown in Table 4-1 . In fact, it is reasonable to suspect that many smaller cities may be experiencing CO problems, particularly during high volume vehicle traffic conditions such as rush-hour traffic in downtown areas or around relatively large and busy shopping centers. There are, however, sufficient data to conclude that reductions in CO emissions are needed in many areas of the country before air quality in these areas meets the national ambient CO standard.

Estimates contained in the Office of Air Quality Planning and Standards (OAQPS), National Emissions Data System (NEDS) Summary indicate that during 1972 over 115 million tons of CO were emitted in the United States by man-made sources. Eighty-two percent (94 million tons) of these emissions are attributed to mobile sources, with the automobile alone accounting for nearly fifty-one% (59 million tons). Among stationary sources, industrial processes account for the largest portion of the emissions (10% of total - 12 million tons). Table 4-2 displays the 1972 national CO emission estimates, along with the distribution of these emissions from the various mobile and stationary sources. It is clearly evident from this table that the majority of CO emissions can be attributed to mobile sources.

Table 4-2

Nationwide Emissions by Source for 1972

Source	NO_x	HC	CO
	Emission in 1,000 of tons/year		
1. Light Gasoline Autos 0-6,000 lbs GVW	4,800	8,610	59,220
2. Light Gasoline Trucks 0-6,000 lbs GVW	870	1,950	10,010
3. Heavy Gasoline Vehicles ≥6,001 lbs GVW	770	2,460	13,510
4. Heavy Diesel Vehicles ≥6,001 lbs GVW	1,190	150	680
5. Motorcycles	<10	170	580
Total Highway Vehicles	7,630	13,330	84,000
6. Non-Highway Mobile Sources	2,600	1,800	10,400
Total Mobile Sources	10,230	15,130	94,400
1. Oil and Gasoline Production and Marketing	0	4,600	0
2. Organic Solvent Use	0	6,000	0
3. Stationary Fuel Combustion	10,800	1,700	1,000
4. Industrial Processes	600	2,900	12,000
5. Solid Waste	200	800	3,200
6. Other Stationary Sources	100	1,200	5,300
Total Stationary Sources	11,700	17,200	21,500
Total U.S.	21,930	32,330	115,900

The measured data listed in Table 4-1 generally reflect areas of high traffic density and are rarely influenced by stationary sources of CO. For the most part, violations of the NAAQS for CO are almost exclusively due to vehicular traffic, and the importance of stationary sources is even less than indicated by the nationwide emissions.

A review of 1973 and available 1974 air quality monitoring data reveals that there are at least 79 AQCR's in which violations of one-hour ambient standard for photochemical oxidants (160 micrograms per cubic meter - ug/m^3) were experienced in one or both years. Those AQCR's are displayed in Table 4-3 along with the measured concentration which constituted the violation. As can be seen from the table, these AQCR's include most of the large urban areas of the country.

Unlike CO, oxidants concentrations tend to be uniformly spread throughout the urban area. Oxidant concentrations above the standard are found in most areas of the country as shown by the 1973 data where nearly 90% of all monitors reporting valid data showed violations of the 1-hour oxidant standard. While most monitoring sites are physically located in or around urban areas, it is generally believed that due to the formation time required for and atmospheric movement of oxidants, large portions of the rural areas are also experiencing oxidant concentrations, at sometime during the year, above the national standards.

OAQPS data indicate that in 1972 nationwide emissions of hydrocarbons (HC), a precursor to oxidants, were almost equally divided between stationary and mobile sources. A distribution of these emissions is displayed in Table 4-2 . As can be seen, the two major sources

Table 4-3
AQCR's Experiencing Violations of The One-Hour NAAQS for Oxidants During 1973 and 1974

AQCR	1973 As of 4/7/75 2nd High $\mu g/m^3$	1974 Partial Year 2nd High $\mu g/m^3$
004 Birmingham	435	280
005 Mobile	206*	280
013 Las Vegas	438	330
015 Phoenix	372	-
018 Memphis	196	240
024 Los Angeles	1156	660
025 N. Central Coast	293	210
028 Sacramento Valley	431	170
029 San Diego	587	340
030 San Francisco	509	170
031 San Joaquin Valley	509	230
032 S. Cent. Coast, Cal.	254	170
033 S. E. Desert, Cal.	548	600
036 Denver	548	500
043 Metro New York	456	350
045 Philadelphia	744	720
047 Washington, D.C.	744	300
050 S. E. Florida	270	-
051 S. W. Florida	215	-
056 Atlanta	195	10
060 Hawaii	166	-
067 Chicago	568	810
070 St. Louis	764	500
072 Paudcah, Ky.	101	200
075 Springfield, Ill.	-	225
077 Owenshoro, Ky.	-	200
078 Louisville	362	200
079 Cincinnati	333	310
080 Indianapolis	225	330
085 Omaha	205	180
092 S. Cent. Iowa	225	500
095 Topeka	190	-
099 S. Cent. Kansas	170	460
103 Ashland, Ky.	146	370
106 S. La. - S. E. Texas	636	390
107 Berlin, N. H.	195	110
115 Baltimore	450	-
117 Pittsfield, Mass.	-	310
118 Worchester	-	350
119 Boston	409	400
120 Providence	274	410
121 Nashua, N. H.	194	230
123 Detroit	208	180
124 Toledo	235	-
131 Minn. - St. Paul	186	130
151 Scranton	-	500
152 Albuquerque	244	180
153 El Paso	-	160
158 Syracuse	344	250
159 Glen Falls, N.Y.	223	220
160 Rochester	231	170
161 Schenectady	356	270
162 Buffalo	280	270
167 Charlotte, N.C.	288	220
171 Asheville, N.C.	210	210
173 Dayton	245	160
174 Cleveland	352	130
176 Columbus	274	90
178 N.W. Penn. -Youngstown	313	130
184 Okla. City	400	310
186 Tulsa	176	160
193 Portland (Ore.-Wash.)	246	260
195 Cent. Pennsylvania	-	250
196 S. Cent. Pennsylvania	-	380
197 S. W. Pennsylvania	-	180
200 Columbia, S.C.	155	280
207 E. Tenn. - S. W. Virginia	568	230
208 Mid-Tennessee	205	340
212 Austin-Waco	313	230
214 Corpus Christi	219	250
215 Dallas	248	290
216 Houston	484	340
217 San Antonio	-	170
220 Salt Lake City	217	240
223 Hampton Roads	215	350
225 Richmond	245	270
229 Puget Sound	78	260
239 S. E. Wisconsin	450	230
240 S. Wisconsin	211	130

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of HC emissions are automobiles and evaporation from stationary sources, such as solvent manufacturing, cleaning, and coating operations. The remaining HC emissions are distributed among a variety of mobile and stationary sources.

While nationwide HC emissions are about equally distributed between stationary and mobile sources, individual AQCR's experience large variations in the contribution of these sources to overall HC emissions. For example, among the AQCR's displayed in Table 4-3 , HC emissions from stationary sources vary from a low of less than 12% of the total to a high of over 70% of the total.

Air quality monitoring data for the period 1972-74 indicate that at least 7 AQCR's are currently experiencing annual concentrations above the national ambient standard (100 ug/m^3) for nitrogen dioxide (NO_2). In addition, there are 12 more cities where the annual NO_2 concentration during 1972-74 was greater than 80% of the standard. It is estimated that NO_2 concentrations in at least 4 of these 12 cities will be above the national standards by the end of 1975. In Table 4-4 the 25 AQCR's discussed above are displayed along with the highest annual NO_2 concentrations (during 1972-74) for each. While it is recognized that there may be other regions of the country experiencing NO_2 concentrations above the annual standard, it is believed that the NO_2 problem is far less pervasive than the situation for oxidants.

Nationwide NO_x emissions during 1972 are estimated to have exceeded 22 million tons, with stationary sources accounting for 57% of the

Table 4-4
Maximum Measured Annual Concentration of NO_2 From 1972-74 Air Quality Data

AQCR 1. Cities Used in Projections		Concentration ug/m^3
015	Phoenix	77
024	Los Angeles	166
030	San Francisco	76
036	Denver	98
043	New York City	121
045	Philadelphia	94
047	Washington, D.C.	97
067	Chicago	133
115	Baltimore	120
131	Minneapolis	65
215	Dallas	52
216	Houston	68
220	Salt Lake City	67
2. Other Cities with High Readings		
174	Canton, Ohio	113
056	Atlanta	90
042	Springfield	111
119	Boston	128
078	Louisville	83
070	St. Louis	87
079	Cincinnati	85
178	Youngstown	96
173	Dayton	90
181	Steubenville	98
234	Charleston, West Virginia	85
239	Milwaukee	81

total. Utility boilers used for electric power generation alone account for 31% of the total NO_x emission, while automobiles account for 22%. Table 4-2 contains a distribution of NO_x emissions for 1972.

In summary, a number of AQCR's are currently experiencing air quality above the ambient standards for the automobile related pollutants. Most of the problems with CO are believed to be primarily due to exhaust emissions from the internal combustion engines. For CO, it is believed that high concentrations are encountered only in the near vicinity of large volumes of mobile source traffic, and are, therefore, mainly confined to the urban areas. Oxidant concentrations above the ambient standard are being monitored in most areas where monitoring equipment is located. It is believed that the oxidant problem is pervasive and not confined solely to the urban areas. While the two largest sources of HC emissions are automobiles and evaporation (solvent manufacturing, cleaning, coating operation, etc.), more than 50% of the total emissions come from many relatively small and diversely located sources, which individually have relatively low HC emission rates. Air quality monitoring data indicate that by the end of 1975, at least 11 AQCR's will experience NO_2 concentrations above the ambient standard. Most man-made NO_x emissions come from fuel combustion processes, with utility boilers (electric power generators) and the automobile being the largest individual source categories.

4.2 1975-80 Air Quality

During the period 1975-80, emission control programs already implemented, as well as those scheduled for implementation in this timeframe, will have a significant impact on air quality. This impact may not be reflected by a large number of the AQCR's discussed in the preceeding section actually attaining the standards during this period; however, the real significance will be in the magnitude of air quality improvement compared to current conditions and between comparisons of 1980 air quality projections with and without these emission control programs. For example, the time period 1975-80 will see most of the relatively uncontrolled (pre-1968) cars replaced with automobiles containing some form of emission control. This event alone will result in considerable reductions in CO, HC, and NO_x emissions. Controls for other classes of mobile sources are expected to be introduced during this time period, and will begin to have some effect by 1980.

The new source performance standard (NSPS) for large utility boilers will reduce NO_x emissions from new or modified plants. The potential impact of this NSPS will, however, not be fully realized because most new boilers will be coal-fired and the present form of the NSPS allows considerably more NO_x emissions from coal-fired boilers than from those using other fossil fuels. In addition, any improvement in emissions for utility boilers will probably be offset by fuel switching orders issued by the Federal Energy Administration.

Future NSPS for solvent manufacturing, cleaning and coating operations will help reduce HC emissions but will have only limited impact by 1980. Controls for evaporative emissions from automobiles, and gasoline handling, and transporting facilities will considerably reduce HC emission from these sources by 1980.

The period 1975-80 will also be a time of research and refinement of technology for control of NO_x emissions from stationary sources. It is currently believed that most of this technology will not be available for full scale implementation until after 1980. However, some of the technology for utility and industrial boilers, because of fuel savings, operational efficiency, and economic considerations, is currently being implemented and its utilization will increase between now and 1980. Also, NSPS for NO_x from stationary gas turbines, stationary internal combustion engines and intermediate size coal, oil, and gas fired boilers are scheduled for implementation during the 1975-80 period.

In a recent EPA analysis[1] which addressed air quality in selected cities, it was found that if the current emission standards for LDV (CO - 15.0 gm/mile, HC - 1.5 gm/mile, NO_x 3.1 gm/mile) remain in effect until after 1980, an average of 19% and 53% improvement in air quality for oxidants and CO, respectively, over the 1972 level would occur by 1980. Under similar assumptions for NO_x emissions, the average air quality in the 10 AQCR's analyzed would deteriorate over the 1972 level by 24%. The above analysis further revealed that if the statutory standards were introduced in 1977 (1978 for NO_x) resulting 1980 air quality would be: a 21% improvement in oxidant concentrations, a 57% improvement in CO concentrations, and a 12% deterioration in NO_2 concentrations, all compared to the 1972 levels.

Assuming that the above changes in air quality occur linearly with time between 1972 and 1980, a critical concentration level in any given year can be determined and used for estimating which AQCR's discussed in Section 4.1 will be above the standards in 1980. For example, if an average improvement in air quality of 35% were expected for a pollutant between 1972 and 1980, and the standard for that pollutant is 100 ug/m^3, then the maximum concentrations the AQCR could experience in 1975 and still expect to meet the standard in 1980 would be 118 ug/m^3.

Using the above approach and the two extreme strategies for LDV emission controls between now and 1980, along with the monitoring data contained in Tables 4-1 , 4-3 , and 4-4 of Section 4.1, the number of AQCR's expected to be above the ambient air standards in 1980 have been determined and are displayed in Table 4-5 . As can be seen, even with substantial improvement in current air quality for oxidants and CO, a large number of AQCR's are not expected to attain the standard by 1980. Because air quality with respect to NO_2 is expected to deteriorate between now and 1980, 20 to 26 AQCR's are expected to exceed the NO_2 standard by 1980.

In summary, oxidant and carbon monoxide concentrations are expected to improve in most areas of the country between now and 1980. On the

Table 4-5

Projected Number of AQCR's above NAAQS Standards Based on Average Improvement in Air Quality for EPA's Alternative Emission Standards for Light Duty Vehicle Analysis

Pollutant	LDV Emissions Standard	Critical Conc*		NO. of AQCR's Above Std. 1973/74	No. of AQCR's Expected to be Above Std in 1980
		1973	1974		
Oxidant	1.5 gm/mi 1975-80	192	186	79	72
	.41 gm/mi 1977-80	196	190	79	72
CO	15 gm/mi 1975-80	19	16	69	29
	3.4 gm/mi 1977-80	20	17	69	27
NO_2	3.1 gm/mi 1975-80	83	85	7	17
	0.4 gm/mi 1978-80	91	92	7	12

* Defined as maximum concentration which can be experienced and still meet standard in 1980 - concentrations are in $\mu g/m^3$ for HC and NO_2 and in mg/m^3 for CO.

average, the improvement will be between 19% and 21% for oxidant, depending upon when and if LDV emissions standards are set more stringent. Similarly, CO concentrations are expected to be reduced by 53% to 57%. Because of expected growth and limited control technology for NO_x emissions, NO_2 concentrations are expected to increase throughout the country during the period 1975-80. It is estimated that this increase will average between 12% and 24%, and will result in 12 to 17 AQCR's being above the NO_2 ambient air standards by 1980.

4.2.1 ISSUES

A. Problems of Achieving Air Quality Standards in The Near Term

The emission control needed to attain national standards for the automobile-related air pollutants is very substantial in a number of cities, as illustrated by the following figures:

Pollutant	Number of AQCR's Where Required Control Exceeds 50%	Maximum Control Required
CO	20	82%
O_x	22	88%
NO_2	00	32%

These figures are based on measured air quality data for 1971 through 1973 and represent a conservative estimate (i.e., other areas may require substantial control, but air quality monitoring data were probably not available for all such areas). Also, these figures represent the emission reduction needed from sources existing during the 1971-73 period; when growth is considered, the overall degree of control is increased.

Although the degree of control needed to attain the NO_2 standard is not as great as for CO and hydrocarbons, the lack of NO_2 control technology makes the problem of attaining and maintaining the standard in those areas presently above or close to the NO_2 standard almost as difficult as for CO and oxidants.

It is clear that the imposition of the statutory auto emission standards, even in 1975 as originally scheduled, would have little effect on air quality in 1977 (the latest date allowed by the Act for attainment of the national standards). Therefore, if standards are to be attained in the 1975 to 1980 time period, very substantial emission reduction must come from existing sources. As indicated in other sections of this report, retrofit technology to achieve such reductions for both mobile and stationary sources is generally not available or feasible. The alternative is source shutdown, either directly, in the case of stationary sources; or, in the case of mobile sources, indirectly through gasoline rationing. EPA considers such measures unreasonable and has asked Congress to amend the Clean Air Act to provide additional time to attain standards in cases where economically and socially disruptive measures would be necessary to attain standards.

B. Problems in Achieving Stationary Source Controls Equivalent to Mobile Source Controls.

The major difficulty in reducing stationary source emissions by the same percentage as mobile sources in the short term relates to the relatively long useful life of stationary sources as compared with mobile sources. Thus, it is possible to have a substantial impact on mobile source emissions in a five to ten year period by focusing only on new vehicles, while substantial control of stationary sources in this time period would require significant retrofit efforts. In many cases, stationary source retrofit technology is not available, and control of existing sources would require basic process changes or fundamental boiler redesign. Essentially, this means an early retirement of such sources and replacement by a new source, obviously at substantial cost. Also, a nationwide mobile source control program for CO and hydrocarbons has been implemented since the mid-1960's and since 1973 for NO_x, while stationary source controls for these pollutants have, for the most part, only recently gone into effect. Even these recent stationary source control programs are not as comprehensive in terms of nationwide applicability as the mobile source control program. Therefore, on a nationwide basis, the control of mobile sources has a substantial "headstart" as compared with stationary sources of CO, hydrocarbons, and NO_x.

4.3 PROJECTIONS OF AIR QUALITY TO THE YEAR 2000

Projections of air quality to the year 2000 were made for the three pollutants, carbon monoxide, photochemical oxidants, and nitrogen dioxide. The air quality was projected for a variety of scenarios based on different emission standards for light duty vehicles. The projections were based on measured air quality representative of years with high pollution concentrations and emissions inventories for a number of air quality control regions. Table 4-6 presents the average change in air quality from the early 1970 period to the year 2000. The percent of those cities which were modeled and which are still expected to have violations of the National Ambient Air Quality Standard in 2000 is also presented in this table.

The detailed results of the calculation showing base year concentrations and projected air quality for 1980, 1990, and 1999 (or 2000) are presented in Tables 4-7 to 4-21. These Tables present the results of the calculations for each urban area or air quality control region. As stated in Section 2.1, these results present estimates of future air quality which are to be used for comparing the relative effects of different growth and control scenarios. The specific projections should only be used with the understanding that uncertainties are inherent in the assumptions used with the analysis. Tables 4-7 to 4-10 contain the results for carbon monoxide, Tables 4-11 to 4-15 contain the results for photochemical oxidants, and Tables 4-16 to 4-21 contain the results for nitrogen dioxide.

The projections are based on assumptions that are expected to be valid to the year 2000. Therefore, actual air quality for 1980 and

Table 4-6

SUMMARY OF AIR QUALITY PROJECTIONS

Pollutant	Light Duty Vehicle Emission Standard Grams Per Mile	Average Percent* Improvement in Air Quality from Base Year to 2000	Percent of Areas* with Violation of Air Quality Standard in 2000
Carbon Monoxide	25.0	67	37
	15.0	76	11
	9.0	80	0
	3.4	85	0
Photochemical Oxidants (Hydrocarbon control)	2.0	39	86
	1.5	41	84
	0.9	46	76
	0.4	50	70
	0.1	52	62
Nitrogen Dioxide	3.1	-29	52
	2.0	-13	33
	1.5	- 7	33
	1.0	0	19
	0.4	10	19
	0.04	15	19

*Based on selected cities and geographic divisions possibly 1990 may not be accurately projected in these Tables. Section 4.2 presents short-term projections to 1980 and 1985. The results of the projections to the year 2000 indicate that stringent controls will be needed before attainment of the National Ambient Air Quality Standards can be achieved.

For carbon monoxide, violations of the air quality standard occur in 2000 whenever the LDV emission standard exceeds 9.0 grams per mile. For photochemical oxidants, one half of the urban areas modeled do not attain the ambient air quality standard, even under stringent stationary source control and a light duty vehicle emission standard of 0.1 grams of hydrocarbon emissions per mile. Air quality, however, is projected to have improved by 52 percent for the most optimistic scenario. These results for oxidants indicate the difficult task of achieving the hydrocarbon reductions needed to achieve the oxidant standard. For the annual average of nitrogen dioxide, air quality deteriorates to the year 2000 except for emission standards more stringent than 1.0 g/mi.

Other assumptions can be made about the emissions expected in the year 2000. For carbon monoxide, low growth rates for light duty vehicles were assumed and stationary sources have only a small impact on the projected air quality. However, for photochemical oxidants and nitrogen dioxide the growth rate of light duty vehicles and stationary sources are important. Table 4-22 and 4-23 summarize the effect that the assumptions have on the projected air quality improvement in the year 2000 for oxidants and nitrogen dioxide. In Table 4-22, some improvement in oxidants air

TABLE 4-7

PROJECTED CO AIR QUALITY

Light Duty Vehicle Emission Standard: 25.0 gm/mile

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004 BIRMINGHAM	18.	9.	6.	6.
009 NORTH ALASKA	35.	18.	13.	13.
013 CLARK-MOHAVE	14.	7.	5.	5.
015 PHOENIX-TUCSON	45.	20.	13.	14.
024 LOS ANGELES	34.	15.	10.	10.
028 SACRAMENTO VA.	34.	16.	11.	11.
029 SAN DIEGO	15.	7.	5.	5.
030 SAN FRANCISCO	18.	8.	6.	6.
031 SAN JOAQUIN	14.	7.	5.	5.
036 DENVER	39.	18.	11.	12.
042 HART-NEW HAVEN	27.	12.	8.	8.
043 NY-NJ-CONN.	52.	23.	15.	15.
045 PHILADELPHIA	34.	16.	10.	11.
047 NAT. CAPITOL	31.	14.	9.	10.
062 E WASH-N IDAHO	20.	9.	6.	6.
067 CHICAGO	35.	17.	11.	12.
080 INDIANAPOLIS	21.	9.	7.	7.
094 KANSAS CITY	19.	9.	6.	6.
115 BALTIMORE	23.	11.	7.	7.
119 BOSTON	29.	13.	9.	9.
131 MINN.-ST. PAUL	14.	7.	5.	5.
178 CENT. NEW YORK	17.	8.	5.	6.
193 PORTLAND	26.	12.	8.	9.
197 S.W. PENNA.	22.	10.	7.	7.
220 WASATCH FRONT	41.	19.	12.	13.
229 PUGET SOUND	24.	11.	7.	8.
999 RMDR SMSAS	18.	12.	8.	8.
AVERAGE PERCENT DECREASE		53.	68.	67.
NO. CITIES ABOVE STD.		17	9	10

Conc: Maximum 8-hour concentration in PPM

Base Year: Base year concentration is highest concentration recorded from 1971 through 1973.

TABLE 4-8

PROJECTED CO AIR QUALITY

Light Duty Vehicle Emission Standard: 15.0 gm/mile

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004	BIRMINGHAM	18.	9.	5.	5.
009	NORTH ALASKA	35.	18.	10.	10.
013	CLARK-MOHAVE	14.	7.	3.	3.
015	PHOENIX-TUCSON	45.	20.	10.	10.
024	LOS ANGELES	34.	15.	7.	7.
028	SACRAMENTO VA.	34.	16.	8.	8.
029	SAN DIEGO	15.	7.	4.	4.
030	SAN FRANCISCO	18.	8.	4.	4.
031	SAN JOAQUIN	14.	7.	4.	4.
036	DENVER	39.	18.	8.	8.
042	HART-NEW HAVEN	27.	12.	6.	6.
043	NY-NJ-CONN.	52.	23.	11.	11.
045	PHILADELPHIA	34.	16.	8.	8.
047	NAT. CAPITOL	31.	14.	7.	7.
062	E WASH-N IDAHO	20.	9.	5.	5.
067	CHICAGO	35.	17.	9.	9.
080	INDIANAPOLIS	21.	9.	5.	5.
094	KANSAS CITY	19.	9.	5.	5.
115	BALTIMORE	23.	11.	5.	6.
119	BOSTON	29.	13.	6.	6.
131	MINN.-ST. PAUL	14.	7.	3.	4.
178	CENT. NEW YORK	17.	8.	4.	4.
193	PORTLAND	26.	12.	6.	7.
197	S.W. PENNA.	22.	10.	5.	5.
220	WASATCH FRONT	41.	19.	9.	9.
229	PUGET SOUND	24.	11.	5.	5.
999	RMDR SMSAS	18.	12.	7.	7.
AVERAGE PERCENT DECREASE			53.	76.	76.
NO. CITIES ABOVE STD.			17	3	3

Conc: Maximum 8-hour concentration in PPM

Base Year: Base year concentration is highest concentration recorded from 1971 through 1973.

TABLE 4-9

PROJECTED CO AIR QUALITY

Light Duty Vehicle Emission Standard: 9.0 gm/mile

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004 BIRMINGHAM	18.	9.	4.	4.
009 NORTH ALASKA	35.	17.	9.	9.
013 CLARK-MOHAVE	14.	7.	3.	3.
015 PHOENIX-TUCSON	45.	20.	8.	8.
024 LOS ANGELES	34.	15.	6.	6.
028 SACRAMENTO VA.	34.	16.	7.	6.
029 SAN DIEGO	15.	7.	3.	3.
030 SAN FRANCISCO	18.	8.	4.	4.
031 SAN JOAQUIN	14.	7.	3.	3.
036 DENVER	39.	17.	7.	7.
042 HART-NEW HAVEN	27.	12.	5.	5.
043 NY-NJ-CONN.	52.	23.	8.	8.
045 PHILADELPHIA	34.	16.	6.	6.
047 NAT. CAPITOL	31.	14.	6.	5.
062 E WASH-N IDAHO	20.	9.	4.	4.
067 CHICAGO	35.	17.	7.	7.
080 INDIANAPOLIS	21.	9.	4.	4.
094 KANSAS CITY	19.	9.	4.	4.
115 BALTIMORE	23.	11.	5.	4.
119 BOSTON	29.	13.	5.	5.
131 MINN.-ST. PAUL	14.	7.	3.	3.
178 CENT. NEW YORK	17.	8.	3.	3.
193 PORTLAND	26.	12.	5.	5.
197 S.W. PENNA.	22.	10.	4.	4.
220 WASATCH FRONT	41.	19.	7.	7.
229 PUGET SOUND	24.	11.	4.	4.
999 RMDR SMSAS	18.	12.	6.	6.
AVERAGE PERCENT DECREASE		54.	80.	80.
NO. CITIES ABOVE STD.		17	0	0

Conc: Maximum 8-hour concentration in PPM

Base Year: Base year concentration is highest concentration recorded from 1971 through 1973.

TABLE 4-10

PROJECTED CO AIR QUALITY

Light Duty Vehicle Emission Standard: 3.4 gm/mile

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004 BIRMINGHAM	18.	8.	4.	3.
009 NORTH ALASKA	35.	17.	8.	7.
013 CLARK-MOHAVE	14.	6.	2.	2.
015 PHOENIX-TUCSON	45.	19.	6.	5.
024 LOS ANGELES	34.	14.	5.	4.
028 SACRAMENTO VA.	34.	15.	5.	5.
029 SAN DIEGO	15.	7.	2.	2.
030 SAN FRANCISCO	18.	8.	3.	3.
031 SAN JOAQUIN	14.	6.	3.	2.
036 DENVER	39.	17.	5.	5.
042 HART-NEW HAVEN	27.	12.	4.	3.
043 NY-NJ-CONN.	52.	22.	7.	6.
045 PHILADELPHIA	34.	15.	5.	5.
047 NAT. CAPITOL	31.	13.	4.	4.
062 E WASH-N IDAHO	20.	9.	3.	3.
067 CHICAGO	35.	16.	6.	6.
080 INDIANAPOLIS	21.	9.	3.	3.
094 KANSAS CITY	19.	9.	3.	3.
115 BALTIMORE	23.	10.	4.	3.
119 BOSTON	29.	12.	4.	4.
131 MINN.-ST. PAUL	14.	6.	2.	2.
178 CENT. NEW YORK	17.	8.	3.	3.
193 PORTLAND	26.	12.	5.	4.
197 S.W. PENNA.	22.	10.	4.	3.
220 WASATCH FRONT	41.	18.	6.	5.
229 PUGET SOUND	24.	10.	4.	3.
999 RMDR SMSAS	18.	11.	6.	6.
AVERAGE PERCENT DECREASE		55.	83.	85.
NO. CITIES ABOVE STD.		17	0	0

Conc: Maximum 8-hour concentration in PPM

Base Year: Base year concentration is highest concentration recorded from 1971 through 1973.

TABLE 4-11

PROJECTED OXIDANT AIR QUALITY

Light Duty Vehicle Emission Standard: 2.0

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004 BIRMINGHAM	.29	.25	.19	.18
005 MOB.-PENSACOLA	.29	.25	.20	.18
013 CLARK-MOHAVE	.22	.18	.14	.13
015 PHOENIX-TUCSON	.19	.16	.12	.11
024 LOS ANGELES	.54	.47	.38	.37
028 SACRAMENTO VA.	.28	.25	.20	.18
029 SAN DIEGO	.32	.26	.20	.20
030 SAN FRANCISCO	.33	.30	.24	.22
031 SAN JOAQUIN	.27	.25	.20	.17
033 SE DESERT	.32	.29	.23	.21
036 DENVER	.33	.27	.20	.20
043 NY-NJ-CONN.	.36	.30	.24	.23
045 PHILADELPHIA	.20	.16	.12	.12
047 NAT. CAPITOL	.38	.31	.24	.24
067 CHICAGO	.30	.29	.24	.20
070 ST. LOUIS	.39	.36	.30	.26
079 CINCINNATI	.19	.16	.12	.11
106 S LOU-SE TEXAS	.32	.28	.22	.21
115 BALTIMORE	.23	.22	.18	.15
119 BOSTON	.21	.17	.13	.12
131 MINN-ST PAUL	.10	.08	.06	.05
153 EL PASO	.13	.10	.06	.07
160 GNSSE-FNGR LKS	.12	.09	.06	.06
173 DAYTON	.16	.13	.10	.09
193 PORTLAND	.15	.13	.10	.09
197 S.W. PENNA.	.17	.14	.10	.10
214 CORPUS-CRISTI	.15	.15	.12	.10
215 DALLAS-FT WRTH	.19	.16	.12	.11
216 HOUSTON-GLVSTN	.38	.37	.31	.26
229 PUGET SOUND	.13	.10	.07	.07
991 REGION 1	.19	.16	.12	.11
992 REGION 2	.19	.16	.12	.11
993 REGION 3	.19	.19	.16	.13
994 REGION 4	.17	.15	.12	.10
995 REGION 5	.17	.14	.10	.10
996 REGION 6	.20	.20	.16	.13
997 REGION 7	.11	.10	.07	.06
AVERAGE PERCENT DECREASE		14.	33.	39.
NO. CITIES ABOVE STD.		36	32	32

Conc: Second highest 1-hour concentration in ppm
Base Year: Base year concentration is second highest 1-hour recorded from 1971 through 1974

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TABLE 4-12

PROJECTED OXIDANT AIR QUALITY

Light Duty Vehicle Emission Standard: 1.5

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004	BIRMINGHAM	.29	.25	.19	.17
005	MOB.-PENSACOLA	.29	.25	.19	.17
013	CLARK-MOHAVE	.22	.18	.13	.13
015	PHOENIX-TUCSON	.19	.15	.11	.11
024	LOS ANGELES	.54	.47	.37	.35
028	SACRAMENTO VA.	.28	.25	.19	.17
029	SAN DIEGO	.32	.26	.19	.19
030	SAN FRANCISCO	.33	.30	.23	.21
031	SAN JOAQUIN	.27	.24	.19	.17
033	SE DESERT	.32	.29	.22	.20
036	DENVER	.33	.26	.19	.19
043	NY-NJ-CONN.	.36	.30	.23	.22
045	PHILADELPHIA	.20	.16	.11	.11
047	NAT. CAPITOL	.38	.31	.22	.23
067	CHICAGO	.30	.29	.24	.20
070	ST. LOUIS	.39	.36	.29	.25
079	CINCINNATI	.19	.16	.11	.11
106	S LOU-SE TEXAS	.32	.28	.21	.20
115	BALTIMORE	.23	.22	.18	.15
119	BOSTON	.21	.17	.12	.12
131	MINN-ST PAUL	.10	.08	.06	.05
153	EL PASO	.13	.09	.06	.06
160	GNSSE-FNGR LKS	.12	.09	.06	.06
173	DAYTON	.16	.13	.09	.09
193	PORTLAND	.15	.13	.09	.08
197	S.W. PENNA.	.17	.14	.10	.09
214	CORPUS-CRISTI	.15	.15	.12	.10
215	DALLAS-FT WRTH	.19	.16	.12	.11
216	HOUSTON-GLVSTN	.38	.36	.30	.26
229	PUGET SOUND	.13	.09	.06	.06
991	REGION 1	.19	.16	.12	.11
992	REGION 2	.19	.16	.12	.11
993	REGION 3	.19	.19	.16	.12
994	REGION 4	.17	.15	.11	.10
995	REGION 5	.17	.14	.09	.09
996	REGION 6	.20	.20	.16	.13
997	REGION 7	.11	.10	.07	.06
	AVERAGE PERCENT DECREASE		14.	36.	41.
	NO. CITIES ABOVE STD.		35	32	31

Conc: Second highest 1-hour concentration in ppm

Base Year: Base year concentration is second highest 1-hour recorded from 1971 through 1974

TABLE 4-13

PROJECTED OXIDANT AIR QUALITY

Light Duty Vehicle Emission Standard: 0.9

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
014 BIRMINGHAM	.29	.24	.18	.16
016 MOB.-PENSACOLA	.29	.25	.18	.16
013 CLARK-MOHAVE	.22	.18	.12	.11
015 PHOENIX-TUCSON	.19	.15	.10	.09
024 LOS ANGELES	.54	.47	.35	.33
028 SACRAMENTO VA.	.23	.25	.19	.16
029 SAN DIEGO	.32	.25	.17	.17
030 SAN FRANCISCO	.33	.29	.22	.19
031 SAN JOAQUIN	.27	.24	.18	.16
033 SE DESERT	.32	.28	.21	.19
036 DENVER	.33	.26	.17	.17
043 NY-NJ-CONN.	.36	.30	.21	.20
045 PHILADELPHIA	.20	.15	.10	.10
047 NAT. CAPITOL	.38	.30	.21	.20
067 CHICAGO	.30	.29	.23	.19
070 ST. LOUIS	.39	.36	.28	.24
079 CINCINNATI	.19	.15	.10	.10
106 S LOU-SE TEXAS	.32	.28	.20	.18
115 BALTIMORE	.23	.22	.17	.14
119 BOSTON	.21	.17	.11	.11
131 MINN-ST PAUL	.10	.08	.05	.05
153 EL PASO	.13	.09	.05	.05
160 GNSSE-FNGR LKS	.12	.09	.05	.05
173 DAYTON	.16	.13	.09	.08
193 PORTLAND	.15	.13	.09	.08
197 S.W. PENNA.	.17	.14	.09	.08
214 CORPUS-CRISTI	.15	.15	.12	.09
215 DALLAS-FT WRTH	.19	.16	.11	.10
216 HOUSTON-GLVSTN	.38	.36	.29	.25
229 PUGET SOUND	.13	.09	.05	.05
991 REGION 1	.19	.16	.11	.10
992 REGION 2	.19	.16	.11	.10
993 REGION 3	.19	.19	.15	.12
994 REGION 4	.17	.15	.11	.09
995 REGION 5	.17	.14	.09	.08
996 REGION 6	.20	.20	.15	.12
997 REGION 7	.11	.09	.07	.06
AVERAGE PERCENT DECREASE		15.	40.	46.
NO. CITIES ABOVE STD.		36	32	28

Conc: Second highest 1-hour concentration in ppm

Base Year: Base year concentration is second highest 1-hour recorded from 1971 through 1974

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TABLE 4-14

PROJECTED OXIDANT AIR QUALITY

Light Duty Vehicle Emission Standard: 0.4

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
004	BIRMINGHAM	.29	.24	.17	.15
005	MOB.-PENSACOLA	.29	.24	.17	.15
013	CLARK-MOHAVE	.22	.18	.12	.10
015	PHOENIX-TUCSON	.19	.15	.10	.08
024	LOS ANGELES	.54	.46	.34	.30
028	SACRAMENTO VA.	.28	.25	.18	.15
029	SAN DIEGO	.32	.25	.16	.15
030	SAN FRANCISCO	.33	.29	.22	.18
031	SAN JOAQUIN	.27	.24	.19	.15
033	SE DESERT	.32	.28	.21	.17
036	DENVER	.33	.26	.16	.15
043	NY-NJ-CONN.	.36	.30	.20	.18
045	PHILADELPHIA	.20	.15	.09	.08
047	NAT. CAPITOL	.38	.30	.19	.18
067	CHICAGO	.30	.29	.23	.18
070	ST. LOUIS	.39	.36	.28	.23
079	CINCINNATI	.19	.15	.10	.09
106	S LOU-SE TEXAS	.32	.28	.20	.17
115	BALTIMORE	.23	.22	.17	.14
119	BOSTON	.21	.17	.11	.10
131	MINN-ST PAUL	.10	.08	.05	.04
153	EL PASO	.13	.09	.05	.05
160	GNSSE-FNCR LKS	.12	.09	.05	.04
173	DAYTON	.16	.13	.09	.07
193	PORTLAND	.15	.13	.08	.07
197	S.W. PENNA.	.17	.14	.09	.08
214	CORPUS-CRISTI	.15	.15	.12	.09
215	DALLAS-FT WRTH	.19	.16	.10	.09
216	HOUSTON-GLVSTN	.38	.36	.29	.24
229	PUGET SOUND	.13	.09	.05	.05
991	REGION 1	.19	.16	.11	.09
992	REGION 2	.19	.16	.11	.09
993	REGION 3	.19	.19	.15	.12
994	REGION 4	.17	.15	.11	.05
995	REGION 5	.17	.14	.09	.08
996	REGION 6	.20	.19	.15	.12
997	REGION 7	.11	.09	.06	.05
	AVERAGE PERCENT DECREASE		15.	42.	50.
	NO. CITIES ABOVE STD.		36	30	26

Conc: Second highest 1-hour concentration in ppm
Base Year: Base year concentration is second highest 1-hour recorded from 1971 through 1974

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TABLE 4-15

PROJECTED OXIDANT AIR QUALITY

Light Duty Vehicle Emission Standard: 0.1

	BASE YEAR	80 CONC	90 CONC	99 CONC
004 BIRMINGHAM	.29	.24	.16	.14
005 MOB.-PENSACOLA	.29	.24	.16	.14
013 CLARK-MOHAVE	.22	.18	.11	.09
015 PHOENIX-TUCSON	.19	.15	.09	.08
024 LOS ANGELES	.54	.46	.33	.29
028 SACRAMENTO VA.	.28	.25	.18	.15
029 SAN DIEGO	.32	.25	.15	.14
030 SAN FRANCISCO	.33	.29	.21	.18
031 SAN JOAQUIN	.27	.24	.17	.14
033 SE DESERT	.32	.28	.20	.17
036 DENVER	.33	.26	.15	.14
043 NY-NJ-CONN.	.36	.30	.19	.17
045 PHILADELPHIA	.20	.15	.09	.08
047 NAT. CAPITOL	.38	.30	.18	.17
067 CHICAGO	.30	.29	.22	.18
070 ST. LOUIS	.39	.36	.27	.23
079 CINCINNATI	.19	.15	.09	.08
106 S LOU-SE TEXAS	.32	.27	.19	.16
115 BALTIMORE	.23	.22	.17	.13
119 BOSTON	.21	.17	.10	.09
131 MINN-ST PAUL	.10	.08	.05	.04
153 EL PASO	.13	.09	.04	.04
160 GNSSE-FNGR LKS	.12	.09	.04	.04
173 DAYTON	.16	.13	.08	.07
193 PORTLAND	.15	.13	.08	.07
197 S.W. PENNA.	.17	.14	.08	.07
214 CORPUS-CRISTI	.15	.15	.12	.09
215 DALLAS-FT WRTH	.19	.15	.10	.08
216 HOUSTON-GLVSTN	.38	.36	.29	.23
229 PUGET SOUND	.13	.09	.04	.04
991 REGION 1	.19	.16	.10	.09
992 REGION 2	.19	.16	.11	.09
993 REGION 3	.19	.19	.15	.12
994 REGION 4	.17	.15	.10	.08
995 REGION 5	.17	.14	.09	.07
996 REGION 6	.20	.19	.15	.12
997 REGION 7	.11	.09	.06	.05
AVERAGE PERCENT DECREASE		16.	44.	52.
NO. CITIES ABOVE STD.		36	28	23

Conc: Second highest 1-hour concentration in ppm

Base Year: Base year concentration is second highest 1-hour recorded from 1971 through 1974

TABLE 4-16

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 3.1 grams/mile

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015 PHOENIX-TUCSON	77.	87.	95.	105.
024 LOS ANGELES	166.	172.	210.	237.
030 SAN FRANCISCO	76.	79.	94.	106.
036 DENVER	98.	112.	128.	132.
043 NY-NJ-CONN.	121.	140.	162.	158.
045 PHILADELPHIA	94.	109.	125.	119.
047 NAT. CAPITOL	97.	111.	128.	131.
067 CHICAGO	133.	155.	177.	169.
070 ST. LOUIS	87.	102.	114.	105.
115 BALTIMORE	120.	140.	159.	152.
131 MINN-ST PAUL	63.	72.	80.	80.
215 DALLAS	52.	59.	65.	68.
216 HOUSTON	68.	79.	88.	82.
220 WASATCH FRONT	67.	76.	87.	92.
991 REGION 1	82.	94.	106.	107.
992 REGION 2	61.	71.	78.	75.
993 REGION 3	41.	47.	52.	50.
994 REGION 4	45.	52.	57.	55.
995 REGION 5	31.	35.	37.	39.
996 REGION 6	36.	41.	44.	44.
997 REGION 7	54.	61.	67.	70.
AVERAGE PERCENT DECREASE		-14.	-29.	-29.
NO. CITIES ABOVE STD.		8	9	11

Conc: Annual average concentration in μg/m^3

Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

TABLE 4-17

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 2.0 grams/mile

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015	PHOENIX-TUCSON	77.	85.	87.	88.
024	LOS ANGELES	166.	167.	176.	190.
030	SAN FRANCISCO	76.	77.	80.	86.
036	DENVER	98.	110.	114.	112.
043	NY-NJ-CONN.	121.	136.	147.	138.
045	PHILADELPHIA	94.	108.	115.	106.
047	NAT. CAPITOL	97.	108.	113.	111.
067	CHICAGO	133.	153.	164.	151.
070	ST. LOUIS	87.	101.	109.	98.
115	BALTIMORE	120.	138.	148.	136.
131	MINN-ST PAUL	63.	71.	74.	71.
215	DALLAS	52.	58.	58.	59.
216	HOUSTON	68.	78.	83.	76.
220	WASATCH FRONT	67.	74.	75.	77.
991	REGION 1	82.	92.	96.	93.
992	REGION 2	61.	70.	73.	69.
993	REGION 3	41.	46.	48.	46.
994	REGION 4	45.	51.	53.	50.
995	REGION 5	31.	34.	34.	34.
996	REGION 6	36.	40.	42.	40.
997	REGION 7	54.	60.	60.	61.
AVERAGE PERCENT DECREASE			-12.	-17.	-13.
NO. CITIES ABOVE STD.			8	8	7

Conc: Annual average concentration in $\mu g/m^3$

Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

TABLE 4-18

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 1.5 grams/mile

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015	PHOENIX-TUCSON	77.	84.	82.	82.
024	LOS ANGELES	166.	165.	162.	169.
030	SAN FRANCISCO	76.	76.	74.	77.
036	DENVER	98.	108.	108.	104.
043	NY-NJ-CONN.	121.	136.	141.	130.
045	PHILADELPHIA	94.	107.	112.	102.
047	NAT. CAPITOL	97.	107.	108.	103.
067	CHICAGO	133.	152.	159.	144.
070	ST. LOUIS	87.	101.	107.	95.
115	BALTIMORE	120.	137.	144.	130.
131	MINN-ST PAUL	63.	70.	71.	68.
215	DALLAS	52.	57.	56.	55.
216	HOUSTON	68.	78.	81.	74.
220	WASATCH FRONT	67.	73.	71.	71.
991	REGION 1	82.	91.	92.	88.
992	REGION 2	61.	69.	71.	66.
993	REGION 3	41.	46.	47.	44.
994	REGION 4	45.	51.	52.	48.
995	REGION 5	31.	34.	33.	33.
996	REGION 6	36.	40.	41.	39.
997	REGION 7	54.	59.	57.	58.

	1980	1990	1999
AVERAGE PERCENT DECREASE	-11.	-12.	-7.
NO. CITIES ABOVE STD.	8	8	7

Conc: Annual average concentration in $\mu g/m^3$

Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

TABLE 4-19

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 1.0 grams/mile

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015	PHOENIX-TUCSON	77.	83.	76.	74.
024	LOS ANGELES	166.	164.	145.	146.
030	SAN FRANCISCO	76.	75.	67.	68.
036	DENVER	98.	107.	101.	95.
043	NY-NJ-CONN.	121.	135.	134.	121.
045	PHILADELPHIA	94.	106.	108.	96.
047	NAT. CAPITOL	97.	106.	101.	94.
067	CHICAGO	133.	151.	153.	136.
070	ST. LOUIS	87.	100.	105.	92.
115	BALTIMORE	120.	136.	138.	123.
131	MINN-ST PAUL	63.	70.	68.	64.
215	DALLAS	52.	56.	53.	51.
216	HOUSTON	68.	78.	79.	71.
220	WASATCH FRONT	67.	72.	66.	64.
991	REGION 1	82.	90.	87.	81.
992	REGION 2	61.	69.	69.	63.
993	REGION 3	41.	46.	45.	42.
994	REGION 4	45.	50.	50.	46.
995	REGION 5	31.	34.	32.	31.
996	REGION 6	36.	40.	39.	37.
997	REGION 7	54.	59.	54.	53.
	AVERAGE PERCENT DECREASE		-10.	-7.	0.
	NO. CITIES ABOVE STD.		7	8	4

Conc: Annual average concentration in $\mu g/m^3$
Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

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TABLE 4-20

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 0.4 grams/mile

		BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015	PHOENIX-TUCSON	77.	82.	69.	64.
024	LOS ANGELES	166.	162.	128.	120.
030	SAN FRANCISCO	76.	74.	60.	57.
036	DENVER	98.	106.	93.	83.
043	NY-NJ-CONN.	121.	134.	125.	109.
045	PHILADELPHIA	94.	105.	102.	89.
047	NAT. CAPITOL	97.	104.	92.	82.
067	CHICAGO	133.	150.	145.	125.
070	ST. LOUIS	87.	100.	102.	88.
115	BALTIMORE	120.	135.	131.	113.
131	MINN-ST PAUL	63.	69.	64.	58.
215	DALLAS	52.	56.	48.	46.
216	HOUSTON	68.	77.	77.	68.
220	WASATCH FRONT	67.	71.	59.	54.
991	REGION 1	82.	89.	81.	73.
992	REGION 2	61.	68.	66.	59.
993	REGION 3	41.	45.	43.	39.
994	REGION 4	45.	50.	48.	43.
995	REGION 5	31.	33.	30.	29.
996	REGION 6	36.	40.	38.	35.
997	REGION 7	54.	58.	50.	48.
	AVERAGE PERCENT DECREASE		-9.	0.	10.
	NO. CITIES ABOVE STD.		7	6	4

Conc: Annual average concentration in $\mu g/m^3$
Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

TABLE 4-21

PROJECTED NITROGEN DIOXIDE AIR QUALITY

Light Duty Vehicle Emission Standard: 0.04 grams/mile

	BASE YEAR	1980 CONC	1990 CONC	1999 CONC
015 PHOENIX-TUCSON	77.	81.	65.	59.
024 LOS ANGELES	166.	160.	117.	106.
030 SAN FRANCISCO	76.	74.	55.	51.
036 DENVER	98.	105.	88.	77.
043 NY-NJ-CONN.	121.	133.	121.	103.
045 PHILADELPHIA	94.	105.	100.	85.
047 NAT. CAPITOL	97.	104.	87.	76.
067 CHICAGO	133.	149.	141.	120.
070 ST. LOUIS	87.	100.	100.	86.
115 BALTIMORE	120.	134.	128.	109.
131 MINN-ST PAUL	63.	69.	62.	56.
215 DALLAS	52.	55.	46.	43.
216 HOUSTON	68.	77.	75.	66.
220 WASATCH FRONT	67.	70.	56.	50.
991 REGION 1	82.	89.	78.	69.
992 REGION 2	61.	68.	65.	57.
993 REGION 3	41.	45.	42.	38.
994 REGION 4	45.	50.	47.	42.
995 REGION 5	31.	33.	29.	27.
996 REGION 6	36.	40.	37.	34.
997 REGION 7	54.	58.	48.	45.
AVERAGE PERCENT DECREASE		-9.	4.	15.
NO. CITIES ABOVE STD.		7	4	4

Conc: Annual average concentration in $\mu g/m^3$

Base Year: Base year concentration is highest annual average recorded from 1972 through 1974

TABLE 4-22

AIR QUALITY PROJECTIONS WITH ADDITIONAL ASSUMPTIONS FOR PHOTOCHEMICAL OXIDANTS

	Assumptions to be Considered		
Light Duty Vehicle Growth	3%*	1%	3%
Stationary Source Control in 2000	75%*	75%	50%
Light Duty Vehicle Emission Standard Grams per Mile	Average Percent Improvement in Air Quality from Base Year to 2000		
2.0	34	44	16
1.5	39	47	19
0.9	43	50	24
0.4	48	53	28
0.1	52	55	31

*Best estimate of future emissions

TABLE 4-23

AIR QUALITY PROJECTIONS WITH ADDITIONAL ASSUMPTIONS FOR NITROGEN DIOXIDE

	Assumptions to be Considered		
Light Duty Vehicle Growth	3%*	1%	3%
Stationary Source Control in 2000	60%*	60%	80%
Light Duty Vehicle Emission Standard Grams per Mile	Average Percent Improvement in Air Quality from Base Year to 2000		
3.1	-29	-11	-2
2.0	-13	-2	14
1.5	-7	2	21
1.0	0	6	28
0.4	10	12	38
0.04	15	15	43

*Best estimate of future emissions

quality occurs for a decreased growth rate, however, the control of stationary sources has a significant impact on air quality. Table 4-23 indicates the same effect for nitrogen oxides. Further discussion of the possible control available and the cost of control is presented in Section 5.0.

For photochemical oxidants, an additional uncertainty exists in the quantitative function used to relate hydrocarbon emissions to ambient oxidant concentrations. The relationship used in the projections presented in Tables 4-11 to 4-15 and 4-22 is based on observed oxidant and hydrocarbon data as presented by the upper-limit relation in Figure 2-2.

There are several reasons for the uncertainty which exists in the relation between oxidants and the emissions which are responsible for them. Oxidants are formed by a complex set of photochemical reactions in the atmosphere. The concentration of oxidants that will be formed depends on both the amounts of organic compounds (hydrocarbons) and nitrogen oxides which are present. The concentration of oxidants also depends on the temperature and the amount of sunlight present. In addition, the oxidants and precursor compounds have been shown to be transported over distances up to 200 km, so that the emissions in one city may affect oxidant concentrations in another. There are also natural sources of the precursor compounds, primarily hydrocarbons, from vegetation and oil and gas field seepage. There is also the possibility for low levels of ozone to be transferred into the lower atmosphere from the stratosphere. The oxidant concentration also depends on the removal mechanisms for the oxidants and their precursors. For example, at night in urban areas the oxidant concentration often drops to near zero because of scavenging reactions.

The interaction of these various factors which determine oxidant concentrations cannot be accurately predicted for each city. The emission rates of nitrogen oxide and hydrocarbons may change so that the ratio of these compounds will change differently in various cities. Laboratory studies show the importance of this ratio to reductions in oxidant concentration. Most of the laboratory studies indicate that the oxidant concentration will be reduced in a less than linear way as hydrocarbon concentrations are reduced. Some laboratory studies show that for certain changes in the ratio of nitrogen oxides to hydrocarbons, the reduction in oxidants is almost linear with hydrocarbon reductions.

The Environmental Protection Agency has used the concept of an upper-limit curve to determine the reductions in hydrocarbons needed to meet the oxidant standard. The concept is that afternoon oxidant concentrations are determined by the hydrocarbon concentration observed from 6 to 9 a.m. of the same day. For a variety of reasons related to the photochemical process, there may be many days that have a higher hydrocarbon concentration, but not as high an oxidant concentration. An upper-limit curve indicates the highest oxidant concentration observed for any given early morning hydrocarbon concentration. It is postulated that if hydrocarbon concentrations are reduced, then oxidant concentration will not exceed that given by the upper-limit curve.

The impact of background is also difficult to assess. Although high rural values of oxidant are observed, they are due primarily to emissions from manmade sources and transport of the oxidant or precursors into the rural area.
As manmade hydrocarbon emissions are reduced, it is expected that the transport of oxidants will be reduced and therefore high oxidant concentrations observed in rural areas. It is possible that natural sources may account for some observed oxidants. The use of 0.05 ppm as a natural background appears to be reasonable. It is, however, not known what

background occurred at the time of the high oxidant concentration used as the base-year value for the projections.

Because there is still uncertainty associated with our understanding of the oxidant forming processes, the actual reduction in oxidants in the future may be different from that projected by that relationship. To provide an estimate of the range of uncertainty, two additional projections of oxidant concentrations were made. Each of these projections was based on the assumption that oxidant concentration would vary linearly with hydrocarbon emissions. In one case it was assumed that there was no background concentration of oxidant and in the other that there is a background of 0.05 ppm. These projections are summarized in Table 4-24.

There is a significant difference in the results obtained by the different functions used. At the statutory emission standard of 0.4 grams per mile the empirical upper-limit relation projects an average improvement of 50 percent in air quality by the year 2000. The linear assumption would project an average improvement of 61 percent if background oxidant concentrations are neglected and a 46 percent improvement if a 0.05 ppm background were assumed.

These differences represent the average improvement for thirty-seven cities and regions. Individual cities may show improvements that differ from these average changes. For example, a background concentration will have less effect on the projected improvement in cities with high concentrations than for cities with low concentrations. There will also be less difference for cities with low concentrations than for cities with high concentration between the projections made from the upper-limit curve and those made from the linear relation with zero background. These effects are illustrated by the comparison of the number of cities which are projected to violate the ambient air quality standard in 2000. For the emission standard of 0.4 grams per mile the upper limit curve projects that 70 percent of the cities modeled will still be in violation of the air quality standard. The linear assumption with zero background projects that this number would be reduced to 49 percent. However, when the background of 0.05 ppm is used, the number of cities in violation of the standard is projected to be 86 percent.

The three methods used to predict oxidant concentrations indicate that, even under stringent control measures, the oxidant standard will not be met in many of the cities. It is predicted, however, that the oxidant concentrations can be reduced by as much as 48 to 63 percent under the most optimistic scenario.

TABLE 4-24

AIR QUALITY PROJECTIONS FOR OXIDANTS WITH ADDITIONAL ASSUMPTIONS ABOUT THE HYDROCARON-OXIDANT RELATIONSHIP

	Average Percent Improvement in Air Quality From Base Year to 2000		
Light Duty Vehicle Emission Standard in Grams per Mile	Upper Limit Relation from Figure 2-2	Linear Relation with 0.05ppm Background	Linear Relation with no Background
2.0	39	37	49
1.5	41	39	52
0.9	46	43	57
0.4	50	46	61
0.1	52	48	63

4.4 HEALTH CONSEQUENCES PROJECTIONS FOR ALTERNATIVE CONTROL STRATEGIES

This section describes the health consequences projections estimated to result from the implementation of varying levels of mobile source emission control assuming fixed levels of light duty vehicle growth.

National health consequences projections are estimated for each of three future years (1980, 1990, 2000) and for the periods 1980 to 2000. Each of the four time frames is displayed for the three automotive related pollutants considered: carbon monoxide, nitrogen dioxide, and photochemical oxidants. Fifteen separate sets of health consequences projections are provided. These are developed for: four carbon monoxide emission assumptions, five hydrocarbon emission assumptions, and six nitrogen oxide emission assumptions.

These projections are based on years which have average air pollutant concentrations. Therefore, although the projections show large numbers of people affected, the effects can be expected to be higher during years when conditions are more conducive to high pollutant concentrations. The projections are for those effects for which dose response relations have been established and do not represent other possible health consequences or synergistic effects. In the following paragraphs these health consequences projections are discussed on a per pollutant basis.

4.4.1 CARBON MONOXIDE

National total estimates of excess cardiac deaths and excess hours of person disability resulting from elevated carbon monoxide levels for each of the five time periods and each of the four automotive emission standards are displayed in Table 4-24. These projections assume that only ten percent of the urban population is exposed to harmful levels of carbon monoxide. They are based on an average year. For typical high years the effects may be fifty or more percent higher than these projected consequences. Figure 4-1 provides a graphical display of projected excess person hours of disability for the period 1980 to 2000 as a function of alternative carbon monoxide emissions standards for light duty vehicles. Figure 4-2 displays projected per

TABLE 4-25

NATIONAL SUMMARY OF PROJECTED HEALTH IMPACT FOR CARBON MONOXIDE

Time Period	Light Duty Vehicle Emission Standard Grams per Mile	Projected Health Consequences: Excess Cardiac Deaths	Projected Health Consequences: Excess Person-hours of Disability
		Average Year	Average Year
Impact in 1980	25.	2.0	33,000
	15.	2.0	33,000
	9.	1.8	31,000
	3.4	1.4	20,000
Impact in 1990	25.	.1	2,900
	15.	.0	0
	9.	.0	0
	3.4	.0	0
Impact in 2000	25.	.1	3,700
	15.	.0	0
	9.	.0	0
	3.4	.0	0
Total Impact Between 1980 and 2000	25.	8	160,000
	15.	7	110,000
	9.	6	100,000
	3.4	5	67,000

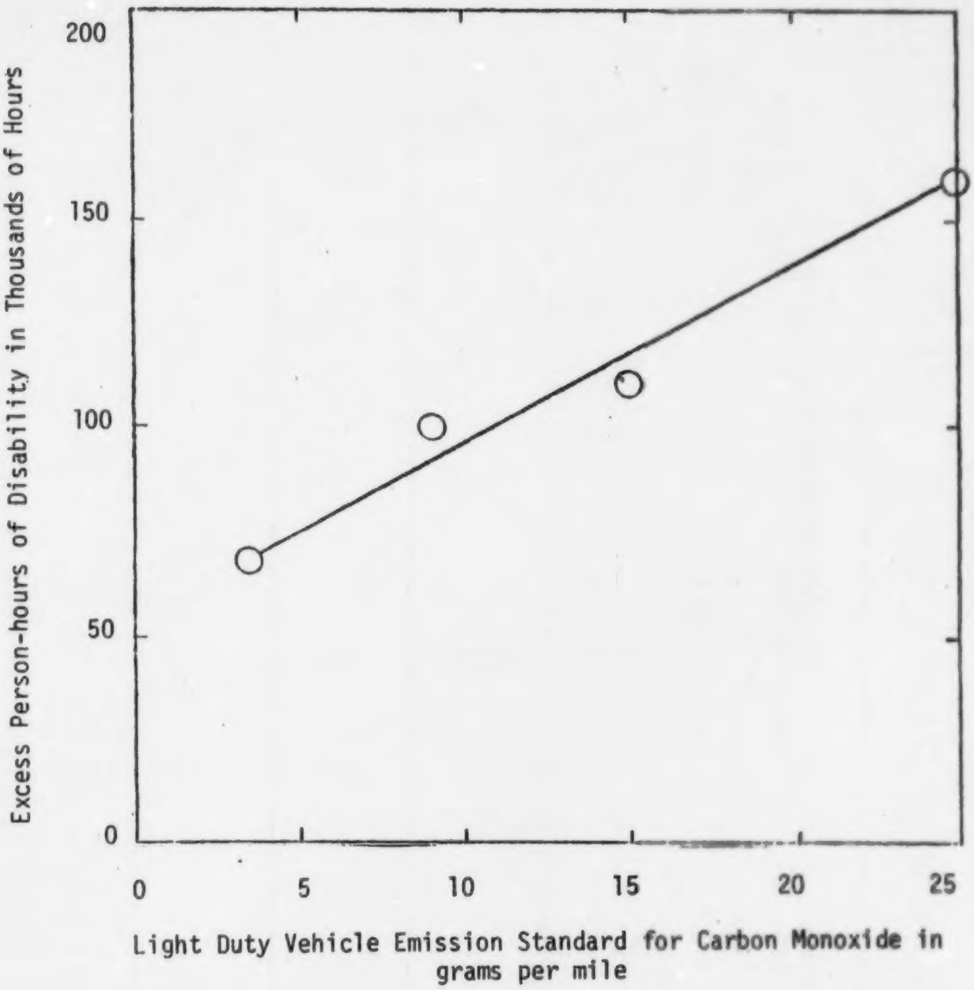

Figure 4-1
Projected Total Health Impact of Carbon Monoxide Exposure
Between 1980 and 2000

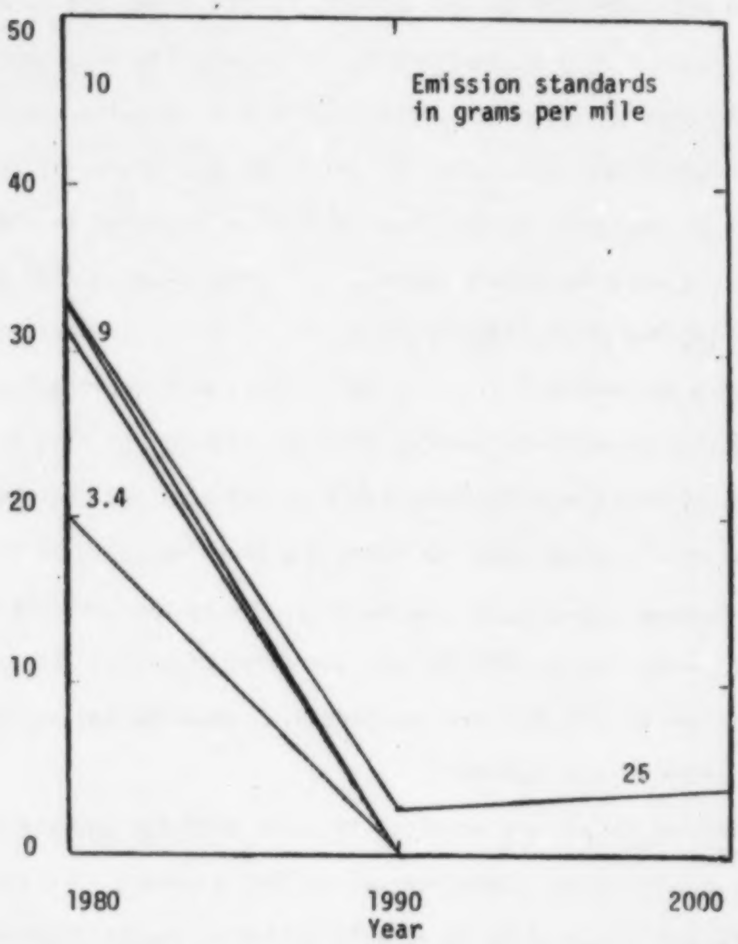

Figure 4-2

Projected Health Impact of Carbon Monoxide
Exposure for an Average Year

year person hours of excess disability at each of the four automotive emission control levels.

The estimates for the period 1980 to 2000 vary from 8 excess deaths for the most relaxed assumptions of carbon monoxide emissions to 5 deaths under the most stringent assumptions of carbon monoxide emissions. On a per year basis the 1990 estimates are lower than those for 1980 or 2000. This can be explained by the level of control expected in 1990 compared to 1980 and expected growth overtaking control between 1990 and 2000.

During the period 1980 to 2000, adverse health effects are projected to be nine percent less if a 9 g/mi standard were implemented rather than continuing with the current emission standard of 15 g/mi. If a 3.4 g/mi standard were implemented, a thirty-nine percent reduction in health consequences is projected. Relaxing the emission standard to 25 g/mi would increase the projected hours of disability by forty-five percent. Most of the health benefit for all scenarios occurs in the near future, as vehicles now on the road are replaced with vehicles having lower emissions.

4.4.2 PHOTOCHEMICAL OXIDANTS

National totals are provided in Table 4-25 for the six health consequences projected for photochemical oxidant exposure: excess aggravation of heart and lung disease in elderly patients; excess aggravation of asthma; excess eye discomfort; excess cough; excess chest discomfort; and excess headache. Figure 4-3 provides a graphical display of projected excess aggravation of heart and lung disease in elderly patients for the period 1980 to 2000 as a function of alternative hydrocarbon emission standards. Figure 4-4 displays projected per year excess aggravation for each level of hydrocarbon emission control.

TABLE 4-26

NATIONAL SUMMARY OF PROJECTED HEALTH IMPACT FOR PHOTOCHEMICAL OXIDANTS

		Projected Health Consequences					
Time period	Light Duty Vehicle Emission Standard Grams per Mile	Aggravation of Heart and Lung Disease in Elderly Patients (in thousands)	Aggravation of Asthma (in thousands)	Eye Discomfort (in thousands)	Cough (in thousands)	Discomfort (in thousands)	Headache (in thousands)
		Average Year	Average Year	Average Year	Average Year	Average Year	Average Year
Impact in 1980	2.0	36	3.6	1800	570	55	2700
	1.5	36	3.6	1800	560	54	2700
	0.9	34	3.4	1700	540	52	2600
	0.4	33	3.3	1700	520	51	2600
	0.1	33	3.3	1700	510	50	2500
Impact in 1990	2.0	15	1.5	790	230	23	1400
	1.5	13	1.3	690	200	19	1200
	0.9	10	1.0	570	160	16	1000
	0.4	9	.9	500	140	14	1000
	0.1	8	.8	430	120	12	900
Impact in 2000	2.0	12	1.2	630	200	19	1100
	1.5	11	1.1	540	170	16	980
	0.9	8	.8	390	120	12	760
	0.4	6	.6	300	90	9	620
	0.1	5	.5	260	80	7	550
Total Impact between 1980 and 2000	2.0	360	36	19000	5600	550	31000
	1.5	330	33	17000	5100	490	28000
	0.9	270	27	16000	4300	430	24000
	0.4	250	25	13000	3900	390	24000
	0.1	230	23	12000	3600	350	22000

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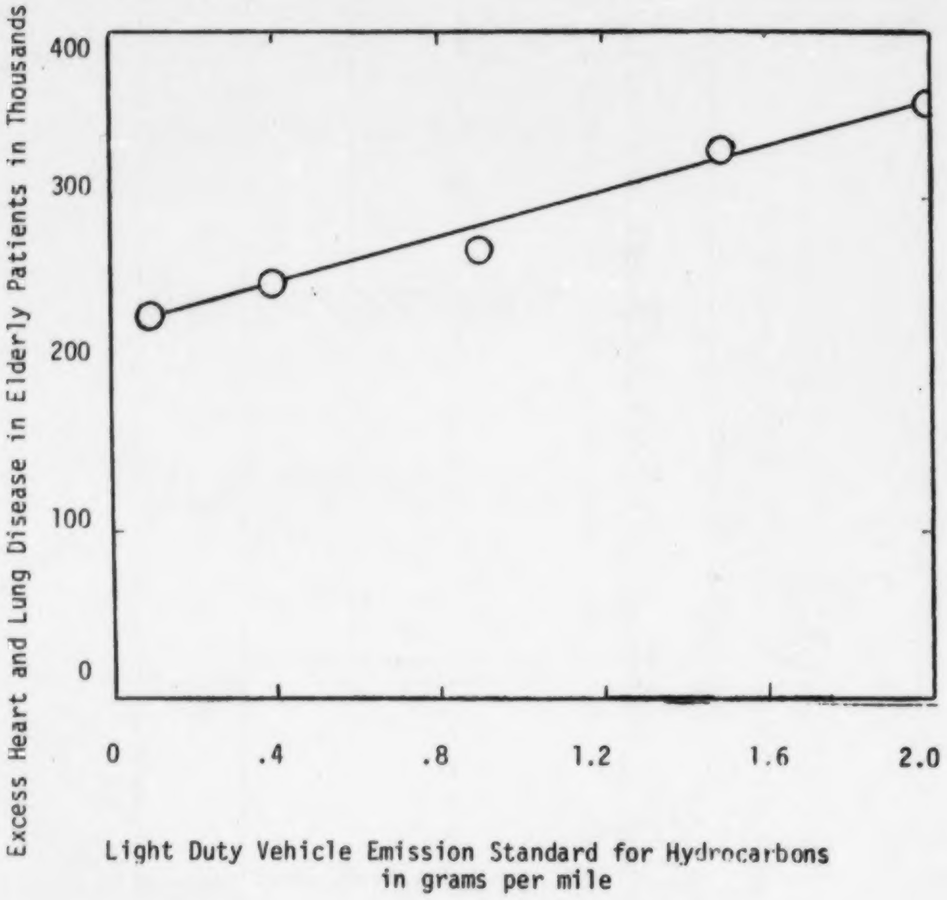

Figure 4-3
Projected Total Health Impact of Photochemical Oxidant
Exposure Between 1980 and 2000

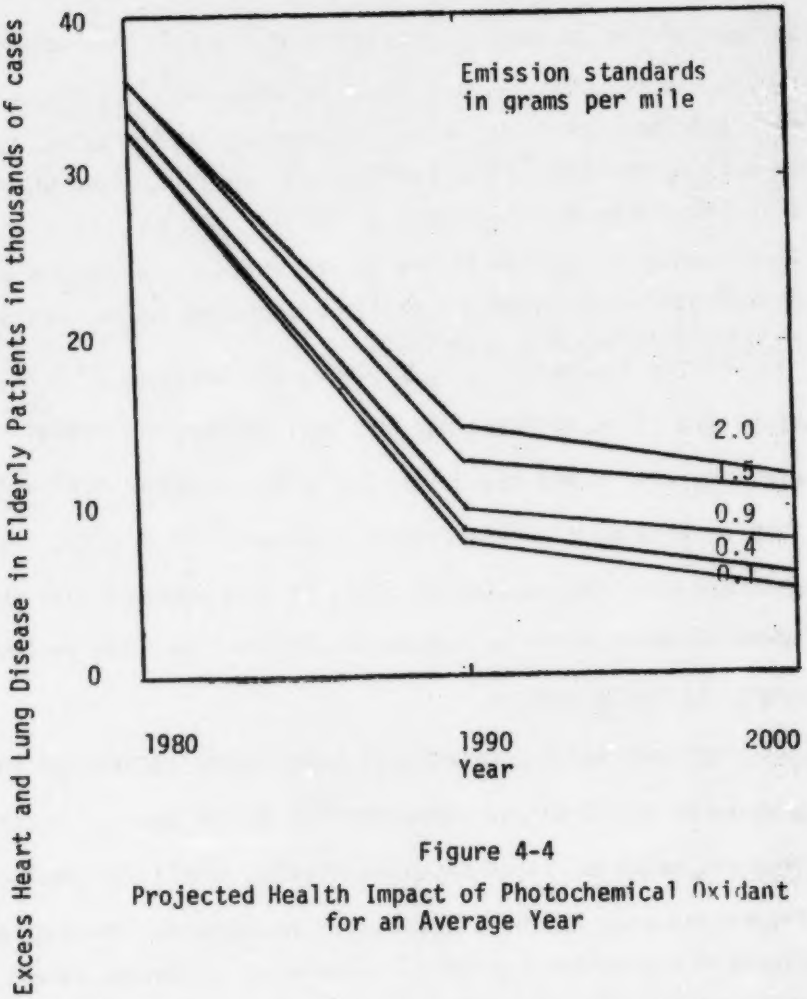

Figure 4-4

Projected Health Impact of Photochemical Oxidant for an Average Year

As can be seen from Table 4-25, there are no emission standards for which aggravation of disease or discomfort are projected to be zero. Some improvement in health is projected for all emissions standards because of the assumption of stringent controls on stationary sources. On a per year basis, as presented in Table 4-25 and Figure 4-4, a significant improvement in health consequences is projected to occur if the statutory emission standard of 0.4 g/mi were implemented. For the year 2000 the change from 1.5 g/mi to 0.4 g/mi causes a reduction in health consequences of between 44 and 53 percent for the various health effects. In high pollutant years the health effects may be as much as twice as great as the projected values indicate.

During the period 1980 to 2000, the total adverse health effects are projected to be eighteen percent less for aggravation of heart and lung disease, asthma and cough if a 0.9 g/mi standard were implemented rather than continuing with the current standard of 1.5 g/mi. If the 0.4 g/mi standard were implemented in 1978, it is projected that the aggravation of these ailments would be reduced by 24% over the 1980 to 2000 period.

4.4.3 NITROGEN DIOXIDE

National total estimates of both excess attacks of lower respiratory disease in children and corresponding excess days of restricted activity from projected elevated nitrogen dioxide levels for each of the five time frames and each of the six emission assumptions are displayed in Table 4-26. Figure 4-5 provides a graphical display of projected excess attacks of lower respiratory diseases for the period 1980 to 2000 as a function of alternative nitrogen oxide emission standards for light duty vehicles. Figure 4-6 displays projected per year excess attacks of lower respiratory disease for each automotive emission control level. For high pollutant years the health consequences may be thirty percent higher than the projected average effects.

Significant differences exist over the period 1980 to 2000 for respiratory attacks projected by continuing with the current 3.1 g/mi

Table 4-27

NATIONAL SUMMARY OF PROJECTED HEALTH IMPACT FOR NITROGEN DIOXIDE

Time Period	Light Duty Vehicle Emission Standard Grams per Mile	Projected Health Consequences	
		Excess Attacks of Lower Respiratory Disease in Children (in thousands)	Excess days of Restricted Activity from Lower Respiratory Disease in Children (in thousands)
		Average Year	Average Year
Impact in 1980	3.1	760	2000
	2.0	740	2000
	1.5	740	2000
	1.0	740	2000
	.4	740	2000
	.04	740	2000
Impact in 1990	3.1	1450	3900
	2.0	880	2300
	1.5	850	2300
	1.0	770	2000
	.4	690	1800
	.04	550	1500
Impact in 2000	3.1	1530	4100
	2.0	960	2600
	1.5	860	2300
	1.0	620	1700
	.4	350	920
	.04	350	920
Total Impact Between 1980 and 2000	3.1	27000	72000
	2.0	17000	46000
	1.5	17000	45000
	1.0	15000	39000
	.4	13000	34000
	.04	11000	30000

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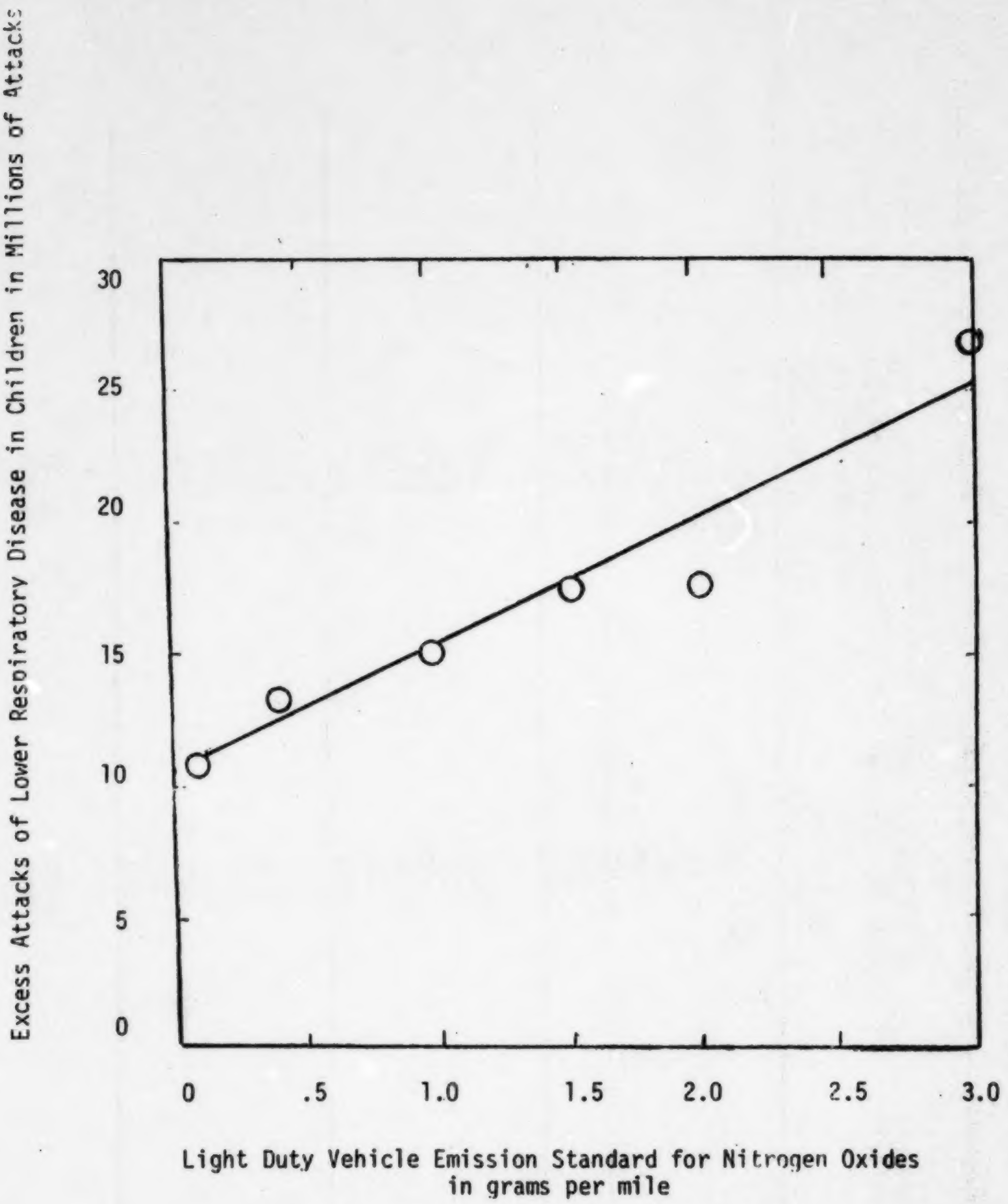

Figure 4-5

Projected Total Health Impact of Nitrogen Dioxide Exposure Between 1980 and 2000

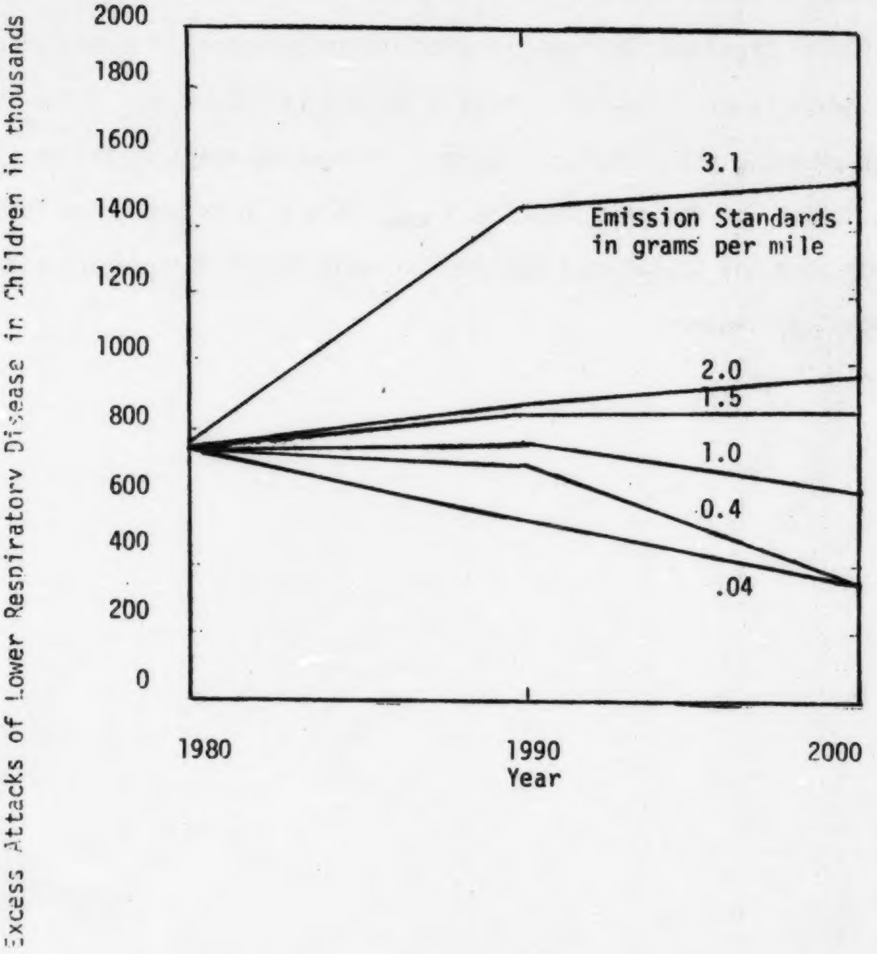

Figure 4-6

Projected Health Impact of Nitrogen Dioxide Exposure for an Average Year nitrogen oxides emission standard versus implementing either a 2.0 g/mi standard or the statutory 0.4 g/mi standard. For the total health impact between 1980 and 2000, a 37 percent improvement is projected for the 2.0 g/mi standard over the present interim standard. The statutory standard is projected to provide a 53 percent improvement. The benefits of implementing the statutory standard are most apparent in the per year estimates for the year 2000, as a 69% reduction is projected for that year when the statutory standard is compared with the present nitrogen oxides emission standard.

4.5 EMISSION OF OTHER POLLUTANTS FROM MOBILE SOURCES

In other sections of this report, the impact of carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxides (NO_x) emissions from mobile sources upon air quality and health have been discussed. The previous discussions have been restricted to these three pollutants because they have historically been considered the major air pollutants from mobile sources. While it is well known that mobile sources produce other emissions which are potentially harmful to health, generally the contribution by mobile sources to the overall problems for the other pollutants is small. Lead and particulate matter are perhaps exceptions, and regulatory action by the Environmental Protection Agency has been initiated to reduce lead emissions by controlling the amount of lead that can be used as a fuel additive. By controlling lead in this manner, particulate matter emissions will also be substantially reduced.

Although CO, HC, and NO_x are the major emissions from today's mobile source fleet, as emission control technology and new types of automotive engines are introduced, other pollutants may become much more important, a good example being the recent concern with sulfuric acid mist emitted from catalyst controlled vehicles. At this time, it is not known what other, if any, potential air pollution problems may arise from such advanced technology as the stratified-charge or Stirling engine; however, it should suffice to say that the Environmental Protection Agency will be carefully monitoring this new technology, and action will be initiated to prevent new air pollution problems brought about by future application of this technology.

The potential for excellent fuel economy makes the diesel engine attractive as a candidate for use in future automobiles. The diesel engine also has some attractive advantages from an environmental standpoint. Indications are that diesel engines could be produced to power automobiles which would meet the statutory CO and HC standards, meet an NO_x standard of 2.0 grams per mile, and still provide considerable improvement in fuel economy as compared to the gasoline engines currently being used. There are, however, potential air pollution problem areas that could arise from widespread use of the diesel engine, particularly, if used as a power plant for automobiles. Among these areas are increased particulate emissions and odors. While it is possible that these problems can be corrected through technological advances, if not controlled they could become serious problems in many areas of the country. Therefore it is prudent to investigate, at least qualatatively, the impact on air quality that could result from diesel powered automobiles.

A number of areas in the country have not been able to attain the National Ambient Air Quality standard for total suspended particulate matter (TSP). Indications are that in many of these areas, it will be very difficult, expensive, and require some rather innovative control technology to bring about attainment. For example, in Phoenix, a large portion of the TSP problem is believed to result from fugitive dust for which control technology is questionable and perhaps not reasonable from a cost standpoint. Any increase in particulate emissions in these areas will neccessitate that the increase be offset by additional controls on other sources, which may already be at or near the limit of reasonableness in the application of control technology.

Mobile source exhaust emissions have contributed significantly to the TSP problems in some of these areas. Although it is not possible to explicitly quantify this contribution, and there are strong reasons to believe the impact varies from city to city, it is generally believed that automotive exhausts contribute between 2 and 13 percent of the total TSP problem in urban areas.

A large portion (80 to 85%) of the particulate emissions from automotive exhaust results from the lead contained in gasoline for anti-knock purposes. The EPA regulations governing the amount of lead which can be contained in gasoline will sharply reduce the particulate emissions from mobile source exhaust. For example, pre-1975 model cars using leaded fuel will, on the average, produce approximately .25 gm/mi of particulate matter. Similar cars using non-leaded fuel will produce on the average, only about .01 gm/mi of particulates, or a reduction of over 99%. An uncontrolled diesel powered automobile is expected to produce approximately 0.4 gm/mi of particulates.

To examine how particulate emissions from the diesel might impact on the TSP problem in a given area, consider a situation where the present annual TSP concentration is 100 $\mu g/m^3$. Assuming that mobile sources account for 8% of the total TSP problem, the reduction in lead usage as a gosoline additive would be expected to reduce the TSP concentration in the area to approximately 93 $\mu g/m^3$. Since the annual NAAQS for TSP is 75 $\mu g/m^3$, the improvement obtained by lead reductions represents approximately 28% of the needed reduction required to meet the ambient standard. This could be very important in those areas where the percent of particulate emissions which can be considered reasonably controllable are small compared to the total particulate emissions, such as areas dominated by fugitive dust or in urban areas where the collective impact of various miscellaneous sources create a rather high "uncontrollable" concentration, frequently called "urban background".

Consider now a similar situation as discussed above, except that gasoline engines are replaced by uncontrolled diesel engines. For this situation, the TSP concentration would be expected to be 104 $\mu g/m^3$. Thus, the act of implementing diesel technology would effectively more than offset the improvement gained through reduced lead-in-gasoline usage. The affected area would be required to implement controls to reduce the TSP concentration by 29 $\mu g/m^3$ rather than 18 $\mu g/m^3$. This increment of 11 $\mu g/m^3$ would have to be obtained by further controlling other sources. Thus whether or not the diesel engine can be considered cost-effective will be dependent, among other things, upon the cost incurred to offset the increased particulate emissions, either by controls on the engine itself, or through additional controls on other sources.

It should be pointed out that the example used above is not too unlike the situation in many cities today. Currently there are approximately 60 AQCR's above the primary ambient TSP standard as the result of "urban background" and another 40 AQCR's which are above the standard primarily because of fugitive dust. This represents nearly 50% of the AQCR's throughout the country. Thus, the nation's TSP problem must be a part of the decision logic to introduce diesel powered automobile engines on a massive scale.

Although substantial reductions in odors from diesel engines have occurred during the last few years, the widespread use of diesel powered automobiles could constitute an odor problem which would not be acceptable to the general public. At this time, the potential levels of the problem are unknown or to what level the public would accept increased odors. Therfore, it can only be stated that the odor problem must also be a part of the decision logic for introducing diesel powered automobiles on a large scale.

The latest information revealed that sulfate emissions could also become a problem with diesel engines. Emission factors show that a 20 fold increase in sulfate emissions will accompany the replacement of current gasoline powered engines with diesel. However, it should also be pointed out that catalyst equipped gasoline powered automobiles could also cause significant increases in sulfate emissions.

5.0 ALTERNATIVE CONTROL STRATEGIES

5.1 INTRODUCTION

In preceeding sections of this report, the results of various control strategies for mobile and stationary sources have been presented. Previous discussions have concentrated on the air quality and health consequences of various control strategies. While specific emission standards for light duty vehicles have been addressed, the alternative strategies for other mobile and stationary sources have been discussed only in terms of a percentage emission reduction compared to the control level available in the 1972-74 time-frame. Also, the previous sections do not address the cost of the various control strategies.

In this section an analysis is made to determine the incremental cost of various levels of emission controls for a variety of mobile and stationary sources. The incremental costs are then used to determine the cost-effectiveness of each level of control. Finally, the various strategies are arranged so that the most cost-effective approach to a given level of control for a particular pollutant can be determined. The cost analysis is restricted to control of hydrocarbons and nitrogen oxides, since no viable option to controlling carbon monoxide from mobile source is believed to exist. This section is concluded by a discussion of the concept and problems of the so-called two car strategy, which basically would extend the current strategy used in the State of California to other parts of the country.

5.2 COST-EFFECTIVENESS OF NO_x CONTROL

In Section 4 of this report, projections of air quality for the year 2000 were presented for various control strategies. A comparison will now be made for the year 2000 between the cost of controlling NO_x emissions from various mobile and stationary sources. The incremental cost will be established for various levels of control for several source categories within both the mobile and stationary source framework. These costs will then be combined with projected emission reductions as a result of the incremental control levels to arrive at a cost-effectiveness ratio for each level of control. These cost-effectiveness ratios will be used to arrive at a series of control strategies which provide the most cost-effective approach to each given level of control.

5.2.1 BASELINE EMISSIONS

Before a comparative analysis between stationary and mobile source emissions in the year 2000 can be made, a baseline case needs to be established. While arguments both for and against can be presented, there appears little doubt that by 1980, a 2.0 gm/mile NO_x standard will be implemented for LDV's. From an available technology and cost standpoint, this standard appears to be the logical point to begin the comparative analysis.[1] It is estimated that by 1980, vehicle miles of travel (VMT) by LDV's will be approximately 9.6×10^{11} miles per year. Assuming a growth rate of 3% per year compounded, for LDV, NO_x emissions in the year 2000 for a standard of 2.0 gm/mile (assuming the average on-road LDV in the year 2000 exactly meets the 2.0 gm/mile standard) is calculated to be:

$$3.8 \times 10^6 \text{ Tons } NO_x\text{/year}$$

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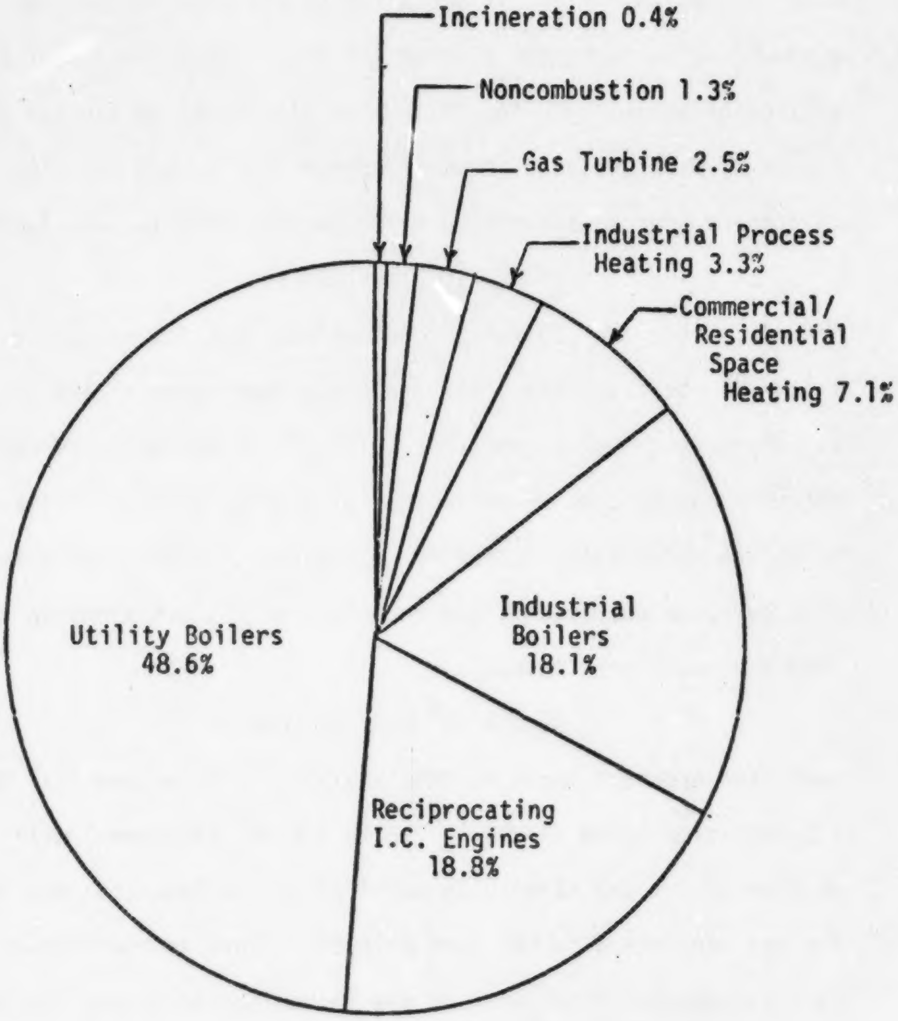
[1] In a later section the cost-effectiveness of reducing NO_x emissions from 3.1 to 2.0 gm/mi will be discussed.

In 1980, it is estimated that the average on-road emission factors for light duty trucks (LDT), heavy duty gasoline vehicles (HDG), and heavy duty diesel vehicles (HDD) will be 3.5, 17, and 26 gm/mile respectively. Also, it is estimated that the 1980 VMT for these three classes of mobile sources will be 2.4 X 10^{11} miles distributed by 60% LDT, 24% HDG, and 16% HDD. Using these values, and collectively classifying the three categories as other mobile sources, the average on-road emission factor for this class (LDT + HDG + HDD) can be calculated to be 10 gm/mile in 1980. Assuming a 3% compounded growth rate, VMT for the other mobile sources is estimated to be 4.3 X 10^{11} miles in the year 2000.

Most likely, by the year 2000 many of the HDG powered vehicles will be replaced with HDD. Therefore, for the baseline case (year 2000), it is assumed that VMT distirbution for other mobile sources will be 60% LDT, 25% HDG, and 25% HDD. Furthermore, for the baseline case it is assumed by the year 2000 emissions for LDT will be reduced to 2.0 gm/mile, and that the interim standards of 13.8 and 20.3 gm/mile for HDG and HDD will remain in effect. Using these values, baseline NO_x emissions from other mobile sources is estimated to be 4.0 X 10^6 tons.

In Reference 6, the total 1972 NO_x emissions from stationary sources were estimated to be 11.7 X 10^6 tons, broken down by various sources as shown in Figure 5.1. During the current study discussions with EPA's Industrial Environmental Research Laboratory (see Reference 7) revealed that an extensive effort was underway to develop NO_x controls for stationary sources. Some 137 different combustion equipment type fuel combinations have been identified as sources of NO_x emissions which have the potential for being controlled through combustion modification. Also, research is underway to determine the feasibility of using flue gas treatment as a means for controlling NO_x emissions from stationary sources. A review of EPA's new source performance standards program indicates that standards for many of the stationary sources will be established by 1980. Although the exact values of these standards are

FIGURE 5-1



Source	Estimated NO_x Emissions Tons/Year
Utility Boilers	5,670,000
Reciprocating I.C. Engines	2,189,000
Industrial Boilers	2,108,000
Commercial/Residential Heating	826,800
Industrial Process Heating	390,200
Gas Turbines	291,000
Noncombustion	149,000
Incineration	41,000
TOTAL	11,665,000

Total NO_x emitted in the U.S. from stationary sources, 1972.

uncertain at this time, it seems reasonable that by the year 2000, at a minimum, an average reduction of 25% of all stationary source emissions will be obtainable. Using this value along with an average growth factor of 3.9% per year (from Reference 2), the NO_x emissions from stationary sources for the baseline case in 2000 is calculated to be:

$$25.5 \times 10^6 \text{ Tons } NO_x/\text{year}$$

However, since the control technology and cost for stationary sources which will be discussed later are based upon uncontrolled emissions, it is necessary to use a projected value of the uncontrolled emissions in determining the cost-effectiveness of the incremental levels of control. Using the information contained in Figure 5.1 and a growth factor of 3.9% per year compounded, the uncontrolled NO_x emissions in the year 2000 are calculated to be:

$$34.2 \times 10^6 \text{ Tons } NO_x/\text{year}$$

Thus, the approach taken in this analysis is to assume that the first 25% reduction (from 34.2×10^6 to 25.5×10^6 Tons/year) will occur whether or not the strategies examined are implemented, and therefore are not considered in the cost anlaysis. This is considered a reasonable assumption, since much of the technology developed (as discussed later) for stationary sources indicates that up to 25% reduction can be obtained through more efficient operating practices. Because of the savings these more efficient operations offer, it is believed they would be implemented even if no emission control requirements are established. Thus for the baseline case, NO_x emissions for the year 2000 are estimated to be:

3.82×10^6 Tons	(LDV)
4.77×10^6 Tons	(Other Mobile Sources)
25.54×10^6 Tons	(Stationary Sources)
34.13×10^6 Tons	(All Sources)

The national emissions cited above do not include emissions from non-highway mobile sources (railroads, aircraft, ships, and non-highway use of motor fuels) and other miscellaneous sources (forest fires). These emissions are estimated to be 3.0×10^6 and 0.2×10^6 tons per year, respectively. Because of their diversity and rural nature most of these emissions are assumed not to cause or contribute significantly to NO_2 air quality problems, and therefore, have been omitted from consideration in the present analysis.

As can be seen from the above figures, for a 2.0 gm/mile LDV standard, and the assumptions used for other mobile and stationary sources, in the year 2000, LDV's account for only 11% of the total NO_x emissions. An attempt will now be made to address the cost-effectiveness of various controls of mobile and stationary sources.

5.2.2 COST AND COST-EFFECTIVENESS OF CONTROLLING LDV's

While various sources have been reviewed in an effort to obtain cost estimates for different LDV NO_x emission standards, it appears that the National Academy of Sciences Study (Reference 8) provides the most acceptable analysis of these costs. Based upon this study and the assumption that the most likely control device for reducing the NO_x standard below 2.0 gm/mile will be a catalyst, the cost of reducing the LDV NO_x emissions from 2 to 1 gm/mile is estimated to be $50.00 over the life of the car. A further reduction to 0.4 gm/mile is estimated to cost an additional $150.00 over the life of the car. The above costs represent average values from the NAS study, and while it is recognized that considerable variability exists in these values, it is believed that they represent the most reasonable approximation to control cost currently available. Assuming the average life of a LDV is 10 years, and it will travel 10,000 miles per year, then the cost-effectiveness of reducing the NO_x standard from 2 to 1 gm/mile can be calculated to be:

$450./Ton of NO_x removed

Similarly, the cost-effectiveness of further reducing NO_x emissions from 1.0 gm/mile to 0.4 gm/mile can be calculated to be:

$2,300./Ton of NO_x removed

Thus it can be seen that reductioning NO_x emissions is five times more cost-effective from 2 to 1 gm/mile than from 1 to 0.4 gm/mile. Potential nationwide emission reductions from LDV's for the 1.0 and 0.4 gm/mile standards, along with the annual costs of these reductions are summarized below:[2]

STRATEGY	TON NO_x REMOVED PER YEAR	COST-EFFECTIVENESS
2.0 to 1.0 gm/mile	1.9×10^6	$450/Ton
1.0 to .4 gm/mile	1.2×10^6	$2300/Ton

Thus, by implementing the 0.4 gm/mile NO_x standard for LDV's a total of 3.1×10^6 tons of NO_x would be removed in the year 2000 at a cost of $\$3.5 \times 10^9$. Recalling that the baseline year emissions were 34.1×10^6 tons, this strategy represents only a 10% reduction of the total NO_x emissions.

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[2] The cost-effectiveness of reducing the LDV NO_x standard from 3.1 to 2.0 gm/mi has been calculated to be $165./ton and will subsequently be discussed.

5.2.3 COST AND COST-EFFECTIVENESS OF NO_x CONTROLS FOR OTHER MOBILE SOURCES

In the baseline case, NO_x emission reductions of approximately 20% over the 1980 level was assumed for other mobile sources. There is considerable speculation over the technology and cost for further emission reductions from these sources, particularly for HDD and HDG. However, the technology panel has provided some estimates of these costs which will be used in the present analysis. The technology panel indicates that existing pre-chamber diesel technology already achieves NO_x levels approximately 70% below current EPA NO_x standards with a 3 to 5% fuel penalty. Furthermore, recent developments in diesel combustion chamber design offers the possible reduction of NO_x levels of 3 gms/BHP-HP as measured by the FTP with no fuel penalty, with simultaneous achievements of low HC and CO levels. Finally, the technology panel indicated that for HDG vehicles the reduction catalyst is the only known technology which can be applied to meet extremely low NO_x levels, and that these reductions can be accomplished without a significant fuel penalty.

Assuming that LDT NO_x emission standards are reduced to 1.0, HDG to 3.0, and HDD to 6.0, the average emission factor for other mobile sources in the year 2000 will be approximately 2.0 gm/mile (VMT distribution - 60% LDT, 25% HDD, 15% HDG). This represents about an 80% reduction in the emission level estimated for 1980 and 60% more than assumed in the baseline case.

To achieve this level of reduction, the costs associated with LDT's can be assumed to be equivalent to that previously estimated for reducing LDV from 2.0 to 1.0 gm/mile, or $450/ton. The technology panel estimates the first cost to achieve this level of NO_x control for HDD will range between $240 and $640. Assuming a first cost of $500., ten year vehicle life, a fuel penalty of 3%, fuel economy of 5 MPG, fuel price $0.60/gal., average use of HDD is 35,000 miles/year, and increased maintenance is $50./year, the cost-effectiveness of further reducing NO_x emissions from 20.3 to 6 gm/mile is estimated to be:

$410/ton

Similarly the technology panel estimates the range of first cost to meet the above level of control for HDG to be between $145. and $350. Assuming a first cost of $300., ten year vehicle life, a 3% fuel penalty, fuel economy of 5 MPG, fuel price of $0.60/gal., average use of HDG is 20,000 mile/year and increased maintenance of $50./year, the cost-effectiveness of further reducing NO_x emissions from 13.8 to 3 gm/mile is estimated to be:

$669/ton

Using the previously discussed assumptions for VMT distribution in the year 2000, the over all cost-effectiveness for the incremental 60% reduction (80% above 1980 level) in NO_x emissions from other mobile sources can be estimated to be approximately $450./ton. The potential emission reduction and cost of this control strategy for other mobile sources are shown below:

STANDARD	TONS NO_x REMOVED	COST EFFECTIVENESS	TOTAL COST
80% Reduction	2.9×10^6	\$450/ton	$\$1.3 \times 10^9$

Perhaps the most debatable assumptions used in the above calculations are those for fuel penalty and maintenance costs. While the values used are admittedly lower than current estimates from manufacturers, it must be realized that there is a 14 year lead time for this technology to be developed and implemented without affecting the results. In light of this lead time, and reports from the technology panel that technology is available, the assumptions do not seem unrealistic.

5.2.4 COST AND COST-EFFECTIVENESS OF NO_x CONTROLS FOR STATIONARY SOURCES

As previously mentioned, EPA's Industrial Environmental Research Laboratory has an extensive research and development program under way aimed at determining the most efficient means of controlling NO_x emissions from stationary sources. Some 137 individual type sources are being identified and prioritized as to their contribution to total NO_x emissions from stationary sources. A comprehensive program to provide combustion control techniques applicable to these sources is under development, and many projects are underway in various stages of development. A good discussion of this program can be found in References 6, 7, 9, and 10.

While the on-going research effort is devoted to many types of sources, these sources can be grouped into the following classifications:

Utility Boilers
Reciprocating I. C. Engines
Industrial Boilers
Commerical/Residential Space Heating
Others

5.2.4.1 UTILITY BOILERS

NO_x controls for utility boilers (mainly power plants) can be classified into two broad areas, combustion modification and flue gas treatment. At the present time, a great deal more research has been conducted on the former than on the latter. Several reports (References 3, 4, 6, and 10) indicate that through combustion modification 30 to 80% control of NO_x emissions can be obtained; the actual amount would be highly dependent upon the type fuel used in firing the boiler.

While the research in flue gas treatment techniques is limited, indications are that more than 90% control of NO_x emissions are possible through this technique. Several full scale processes are reported to be in operation that provide NO_x reductions up to 90% (References 11 and 12).

Combustion modification consists of using such techniques as Low Excess Air (LEA), Staged Combustion (SC), Flue Gas Recirculation (FGR), Water Injection (WI), and Burner Design (BD). References 3, 4, 5, and 6 indicate that the most economical and technically feasible form of combustion modification is through the use of LEA. A review of these references reveals approximately 25% reduction of utility boiler emissions can be obtained through this technique without a significant increase in cost for modern boilers and for a relatively small investment for boilers requiring modification. In fact, fuel savings as a result of improved operating efficiency will probably more than offset any cost associated with adapting the boiler to use the LEA principles. Since this technique is expected to be available by 1980, it is used as the first 25% reduction assumed in calculating the baseline emissions.

The next step in combustion modification appears to be some form of either LEA plus FGR or LEA plus SC, depending upon the type boiler involved. Reference 6 shows that the annual operating cost of using a combination of overfired-air (a form of SC) and FGR for a new 750 megawatt coal fired boiler is $446,000 (cost includes annual fixed charges and additional fan power cost). Reference 11 tends to confirm this figure. It is currently estimated that this process can be made available for new utility boilers by 1982 and for most existing boilers by 1985. From References 3, 4, 6, and 11 it is estimated that this process will provide an average of 50% reduction in NO_x emissions from utility boilers, and based on cost estimates contained in these references the incremental cost of obtaining the additional 25% reduction (above the 25% for LEA) is estimated for new sources to be an average of $100.00 for each ton removed (assuming new sources average around 750 megawatt capacity). The 50% figure and cost estimate are used as an average of all types of utility boilers (oil, coal, and gas). Additional information in Reference 6 indicates that existing utility boilers would experience an incremental cost of approximately 1.5 times that for new sources; however, Reference 14 indicates that California Edison, has experienced a marginal cost of slightly over $300/ton for this control technique on existing oil and gas fired 750 megawatt boilers. Therefore, it is assumed that for existing utility boilers, the cost-effectiveness of using this technique will average $225.00/ton.

Assuming that utility boilers have a 30 year life, and that after 1980 all new and modified boilers are designed to be amenable to the above controls, by the year 2000 85% of all utility boilers will fall into the new source category above ($100/ton for between 25 and 50% removal) while the remaining 15% will be in the existing category ($225/ton for 25-50% removal). From Figure 1 and using a growth rate of 3.9% per year (Reference 2), uncontrolled emissions in 2000 from utility boilers are estimated to be 16.6 X 10^6 tons. Applying the previously assumed reduction of 25%, the baseline emissions for utility boilers in 2000 are 12.4 X 10^6 tons. Assuming that through the next level of combustion modification (LEA plus SC, etc.) an additional 25% reduction (total of 50%) in emissions (over the uncontrolled level) can be obtained, the potential reductions and incremental cost for this control is listed below:

	TONS NO_x REMOVED	COST-EFFECTIVENESS	TOTAL COST OF STRATEGY
New Sources	3.52 X 10^6	$100/ton	$0.35 X 10^9
Existing Sources	0.62 X 10^6	$225/ton	$0.14 X 10^9

There appears to be two different approaches to flue gas treatment for NO_x control. The first consists of injecting ammonia into the flue gas after applying the second level of combustion modification. Reference 11 indicates that this technique can provide up to 75% control (25% above that obtainable with combustion modification) at an incremental cost of $1,100.00 for each ton removed from a typical coal fired boiler operating 5700 hours per year. Assuming the technique will be available in 1985 and will be amenable to both existing and new sources by 2000, the potential reduction and incremental cost for this technique are shown below:

TONS OF NO_x REMOVED	COST EFFECTIVENESS	INCREMENTAL COST
1.03×10^6	$1,100/ton	$\$1.10 \times 10^9$

The final technique for flue gas treatment consists of using a catalyst in conjunction with the two levels of combustion modification. Very little experience has been gained with this technique although two companies (References 11, 12, and 13) indicate they have full-scale versions available and have obtained a 90% reduction in NO_x emissions. In addition, Reference 9 points out that research has indicated this technique is feasible and that commerical units could be designed which would provide NO_x reductions in excess of 90%. There are considerable differences between the cost estimates contained in Reference 9 and 11. For example, Reference 9 indicates that a unit could be built for new 800 megawatt power plants at an annual cost of $\$2.5 \times 10^6$ and for an existing 800 megawatt plant for $\$4.00 \times 10^6$. However, Reference 11 estimates a unit for a 800 megawatt plant to have an annual cost of approximately $\$11.4 \times 10^6$ (plant operating at 5700 hours/year). Since this technique will provide 40% more reduction in NO_x emissions than the two levels of combustion modification, on an incremental cost basis, the data from References 9 and 11 are computed for a 800 megawatt coal fired power plant (operating 5700 hrs/yr) to be:

Reference 9	New Sources:	$370/ton
	Existing Sources:	$580/ton
Reference 11	New Sources:	$1700/ton

At this point it is not known which of the two references best estimates the cost of this technique; therefore, an in-between value of $1200/tons is assumed. As will be seen later, the assumption of $1200/tons does not affect the order of this control technique when determining the most cost-effective strategy to apply for a given level of emission reduction. It is assumed that this cost is applicable to both new and existing sources. The potential for NO_x emission reductions through this technique along with cost are shown below:

TONS OF NO_x REMOVED	COST EFFECTIVENESS	TOTAL COST OF STRATEGY
6.62×10^6	$1,200/ton	$\$7.94 \times 10^9$

Since the cost-effectiveness for 90% control is only slightly different from the technique for 75% control (injection), only the 90% control technique will be discussed further.

Three levels of NO_x controls for utility boilers have been studied and are summarized below:

Level	Technique	Incremental Control Level	Cumulative Control	Cost Effectiveness
1	LEA	25%	25%	Assumed to be applied to baseline emissions
2	LEA plus SC (or FGR)	25%	50%	$100/ton New Source $225/ton Existing Source
3	Level 2 plus catalyst control of flue gas	40%	90%	$1200/ton

Throughout the remainder of the paper, these techniques will referred to by levels 1, 2, or 3.

5.2.4.2 STATIONARY INTERNAL COMBUSTION ENGINES

EPA's Office of Air Quality Planning and Standards is currently reviewing the stationary internal combustion engine as a candidate for a new source performance standard. While control studies for this source are not complete, preliminary estimates indicate that on the average, 25 to 30% control can be obtained through exhaust gas recirculation (EGR) at a cost of approximately $200./ton of NO_x removed. Since the baseline emissions for this study assumes a 25% reduction in all stationary sources, this reduction is assumed to be applicable to the baseline emissions.

An effort to ascertain cost estimates for additional control of stationary IC engines proved fruitless during the present study effort. While a number of techniques are under consideration (i.e., Optimum Air/Fuel Ratio, Water Injection, Modified Fuel Injection Timing, Variable Compression Ratio, and Exhaust Treatment) it is apparently too early to estimate the cost of these controls. However, from an operational standpoint it would appear that controls for stationary IC engines would be less expensive than controls for mobile sources, particularly the larger engines. Therefore, for this study, it is assumed that an equivalent reduction in 90% of the emissions from stationary IC engines can be achieved at 75% of the cost for mobile sources. However, 10% of the stationary IC engine emissions are assumed to be from smaller engines (such as lawn mower engines) for which it is not believed a cost-effective approach to controls will be available.

Under this assumption, the cost-effectiveness ratio of reducing NO_x emissions from 25% (baseline) to 75% is computed to be $340./ton (75% of the cost in reducing LDV's from 2 to 1 gm/mile) while the cost-effectiveness ratio of further reducing emissions from 75% to 90% is computed to be $1700./ton (75% of cost in reducing LDV's from 1.0 to 0.4 gm/mile).

From Figure 1 and assuming a growth rate of 3.9% per year, uncontrolled emissions from stationary IC engines in the year 2000 are calculated to be 6.40×10^6 tons. Accounting for the 25% baseline reduction and the 10% which was assumed uncontrollable, emissions in 2000 from stationary IC engines are estimated to be 4.31×10^6 tons. Potential emission reductions and associated costs from this source are estimated to be:

Level of Control	Tons of NO_x Removed	Cost-Effectiveness	Total Cost Of Strategy
25 to 75%	2.87×10^6	$340/ton	$0.98 X 10^9
76 to 90%	0.86×10^6	$1700/ton	$1.46 X 10^9

5.2.4.3 INDUSTRIAL BOILERS

A large portion of the research effort underway for stationary source controls is being devoted to industrial boilers. Generally, the controls previously discussed for utility boilers are also applicable to boilers in the industrial category, and the same levels of control are obtainable by various techniques. However, as noted in Reference 6, cost estimates of these controls are virtually non-existant. Based upon a number of conversations with knowledgeable people, it has been concluded that an equivalent emission reduction through combustion modification techniques for industrial boilers will be approximately 1.5 times more expensive than for utility boilers, and it is doubtful that widespread use of flue gas treatment will prove cost-effective for this source. In view of the lack of cost estimates for NO_x controls of this source and the fact that burner redesign appears to be promising, it is estimated that, on the average, 65% control can be made available by 1982 at a cost-effective ratio of 1.5 times that experienced for level two control of utility boilers.

From Figure 1, and assuming a 3.9% growth rate, baseline emissions for the year 2000 from industrial boilers is calculated to be 4.62×10^6 tons. The potential emission reductions, incremental cost and total cost for this source are shown below:

Level of Control	Tons of NO_x Removed	Cost-Effectiveness	Total Cost Of Strategy
25 to 65%	2.46×10^6	$150/ton	$\$0.37 \times 10^9$

5.2.4.4 OTHER STATIONARY SOURCES

The remaining stationary sources, which encompass only about 15% of the total emissions from stationary sources, are grouped into a single category for discussion. Research on various sources in this category is presently on-going; however, very little information beyond bench scale work is available, and except for gas turbines and nitric acid plants, the cost of NO_x controls is virtually non-existant. In discussions with EPA's Industrial Environmental Laboratory it was learned that through burner redesign, a possible reduction of up to 50% for NO_x emissions from commercial/residential space heaters could be obtained without an increase in cost over current heaters. In addition, preliminary work indicates that a catalyst costing $250.00 for residential and up to $2000.00 for larger commercial units would be more cost-effective compared to some of the other techniques discussed for NO_x control. While a good possibility exists for control of NO_x sources in this category, no control beyond the baseline emissions is considered in this study.

5.2.5 RESULTS AND DISCUSSION

The NO_x emissions from various sources considered in the present analysis for the year 2000 are summarized in Table 5.1, along with the various levels of control considered to be available. It should be noted that level of control is expressed in terms of baseline emissions, defined as 2.0 gm/mile LDV standard, 10.0 gm/mile other mobile source standard, and a 25% reduction in NO_x emissions from stationary sources as compared to 1972. Thus, for stationary sources, the actual control being considered is 25% plus the value shown in the Table. It can be seen from Table 5.1 that in the year 2000, utility boilers are projected to constitute a large portion of the NO_x emissions, assuming no more than 25% control is obtained.

In Table 5.1, the various strategies previously discussed for NO_x control are ranked according to their cost-effectiveness beginning with the most and progressing to the least cost-effective strategy. Also shown in the table are the amounts of emission reduction possible through each strategy, the percent of the baseline emissions (34.12×10^6 - Table 5.1) each strategy represents, and the incremental and total cost

TABLE 5.1

PROJECTED EMISSIONS DISTRIBUTION AND CONTROL AVAILABLE IN 2000

SOURCE	BASELINE* EMISSIONS (Tons)	% OF BASELINE* NO_x EMISSIONS	LEVEL OF CONTROL AVAIL. ABOVE BASELINE
LDV	3.82×10^6	12	80%
Other Mobile	4.00×10^6	12	75%
Utility Boilers	12.41×10^6	37	65%
Sta. IC. Engines	4.81×10^6	14	65%
Industrial Boilers	4.61×10^6	14	40%
Other Stationary	3.72×10^6	11	0
TOTAL	33.35×10^6	100	

*Baseline Emissions are based on LDV Standard of 2.0 gm/mi, Other Mobile 10 gm/mi, 25% control of all Stationary Sources.

of the stragety. All cost values are in terms of 1975 dollars. Also shown are cumulative costs as various levels of control are obtained. Thus, given the desired level of emission reduction required in the year 2000, the most cost-effective approach to obtaining the reduction on a nationwide basis can readily be obtained. For example, if 27% reduction in the baseline emissions of 33.35 X 10^6 tons is required, then the most cost-effective approach would be to implement the first four strategies shown in Table 5.2.

From previous discussions, and Table 5.2, it can be determined that a reduction in LDV emissions standards from 2.0 to 0.4 gm/mile would result in a reduction of 3.1 X 10^6 tons of NO_x in 2000 and would cost \$3.5 X 10^9. For approximately the same amount of money, the first five strategies in Table 5.2 could be applied resulting in more than four times the NO_x emission reduction obtainable through the change in LDV standards from 2.0 to 0.4 gm/mile. Table 5.2 further indicates that a number of the strategies for stationary source control are more cost-effective than mobile source control below 2.0 gm/mile.

The results of the present analysis are displayed graphically in Figure 5.2 using cost as a function of tons of NO_x removed. Three categories are shown; (1) The cost vs tons of NO_x removed for mobile sources, (2) cost vs tons of NO_x removed for stationary sources, and (3) cost vs tons of NO_x removed for combined mobile and stationary sources. Each curve represents the most cost-effective approach for the three individual categories. As an example of how the figure might be used, consider a situation in which it is desired to determine the amount of

Table 5.2

COST-EFFECTIVE STRATEGIES FOR CONTROL OF NO_x EMISSIONS

CONTROL STRATEGY	NO_x REMOVED (10^6 tons)	% OF BASELINE EMISSIONS**	CUL % OF BASELINE	COST-EFFECTIVENESS ($/ton)	ANNUAL COST OF STRATEGY (billion $)	CUL-ANNUAL COST (billion $)	CUL NO_x REMOVED (10^6 tons)
New Utility Boilers From 25% to 50% Control	3.52	11	11	100	0.35	0.35	3.5
Industrial Boilers From 25% to 65% Control	2.46	7	18	150	0.37	0.72	6.0
Exist. Util. Boilers From 25% to 50% Control	0.62	2	20	225	0.14	0.86	6.6
Sta. IC Engines From 25% to 75% Control	2.87	9	29	340	0.98	1.84	9.5
Other Mobile From 10 gm/mile to 80% Control	2.9	9	38	450	1.3	3.14	12.4
LDV From 2.0 to 1.0 gm/mile	1.91	6	44	450	0.86	4.0	14.31
Util. Boilers From 50% to 90% Control	6.62	20	64	1200	7.94	11.94	20.93
Sta. IC Engines From 75% to 90% Control *	0.86	3	67	1700	1.46	13.43	21.79
LDV to 0.4 gm/mile	1.15	3	70	2300	2.65	16.08	22.94

* STA IC ENG Control Does Not Include Small Engines

** Baseline Emissions = 34.1 X 10^6 Tons in 2000 and is Based Upon - LDV Standard 2.0 gm/mile Other Mobile 10 gm/mile, 25% Control of All Stationary Source Emissions.

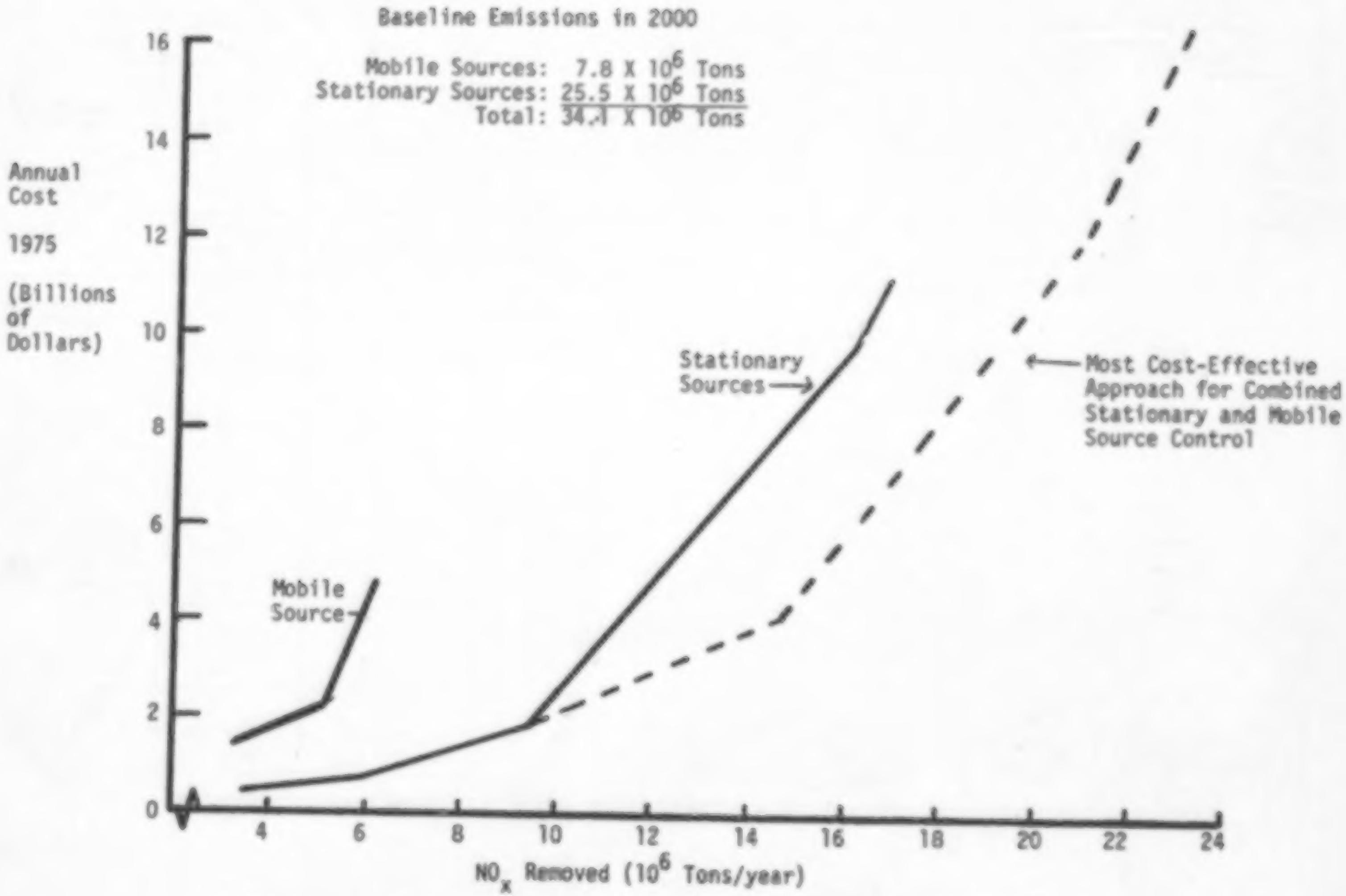

Figure 5.2 Comparison of Cost VS Tons of NO_x Removed From Baseline Case for Mobile Sources, Stationary Sources, and Optimum Cost-Effective Strategy, For The Year 2000.

emissions which can be obtained at an annual cost of 5 billion dollars. By controlling only mobile sources, a reduction of 6 million tons could be obtained. If the 5 billion were invested in stationary source control only, 12.1 million tons could be removed. However, by using the most cost-effective combinations of mobile and stationary source control, 15 million tons of NO_x could be removed. Similarly, consider a situation where it is necessary to remove 16 million tons of NO_x in order to meet the ambient standard. From Figure 5.2 it can be seen that only 6.0 million tons of NO_x can be removed by the mobile source strategies examined. If the entire 16 million tons were to be removed from stationary sources only, the cost would be approximately 9.5 billion dollars. However, by using the optimum combination (with respect to cost) of mobile and stationary source control, the 16 million tons could be removed for approximately 6 billion dollars. These two examples clearly illustrate the advantages of using a cost-effective approach for emission reduction.

5.2.6 REASONABLENESS OF CONTROL LEVELS INVESTIGATED

In the preceeding analysis, control levels were investigated which represent approximately 75% control of all stationary source NO_x emissions. The air quality analysis contained in Section 4.3 of this report was based upon an assumed control level of 60% for stationary source NO_x emissions by the year 2000.

The across the board 25% reduction assumed in the baseline case plus the first four strategies shown in Table 5.2 represent approximately 53% control of all stationary source emissions. It can be seen that stationary source control levels beyond the first four strategies in Table 5.2 represent technology which is in the earlier stages of research. Also the cost figures used for this advanced technology are very speculative. Thus for the air quality analysis in Section 4.3, the 60% control level relative to 1972 represents a value between what can now be considered reasonable control and what current research indicates may be possible in future years.

5.2.7. APPLICABILITY OF ANALYSIS TO INDIVIDUAL CITIES

The discussion in the preceeding sections has been based upon nationwide emissions (approximately equal between stationary and mobile sources). The results can be directly applied to a specific city, provided the distribution of mobile and stationary sources are similar to the nationwide distribution. The number of strategies which would have to be implemented will be dependent upon the current NO_2 concentration, predicted growth rates, and the distribution of various sources. For example, a specific city may have relatively few emissions from utility boilers, and many from LDV's. Since there are several cities where LDV's account for nearly 50% of the total NO_x emissions (i.e., Los Angeles, San Francisco, and Phoenix), a hypothetical city is examined to determine how many of the nine strategies may be necessary in order to meet the NO_2 ambient air quality standard.

Assume that a city had an NO_x emission inventory in 1972 as shown below:

Mobile Sources		215,000
LDV	171,000	
Other	44,000	
Stationary Sources		115,000
Utility Boilers	56,000	
I C Engines	22,000	
Industrial Boilers	21,000	
Other	16,000	
Total 1972 Emissions		330,000

Thus through application of the first eight strategies in Table 5.2, a total reduction in NO_x emissions of 59% would be experienced by the year 2000. Applying the simple rollback model, and assuming that the background concentration is 8 ug/m^3, it can be determined that the hypothetical city would meet the NO_2 standard, if the concentrations in 1972 were less than 163 ug/m^3. Only Los Angeles (148 ug/m^3 in 1972) experienced a NO_2 concentration of this magnitude during 1972. Depending upon future growth rates, Los Angeles may require all nine strategies to be implemented.

The results shown in Table 5.2 indicate that controlling LDV's from 2.0 gm/mile to 1.0 gm/mile is more cost-effective compared to some of the stationary source controls examined. In the hypothetical example of the preceeding section, if LDV's were controlled to only 2.0 gm/mile, then emissions in 2000 would be 294,000 tons, which would be only an 11% reduction over the 1972 emissions. Application of the simple roll-back model under the same assumptions previously used shows that the hypothetical city would not meet the ambient NO_2 standard if the 1972 concentration exceeded 111 ug/m^3. A number of cities have NO_2 concentrations approaching or exceeding this value; therefore, there is reason to suspect that reducing LDV NO_x emissions to at least 1.0 gm/mile will be necessary.

5.2.7 DEPENDENCY OF RESULTS UPON ASSUMPTIONS

The analysis contained in this paper assumes that the various levels of control for stationary sources can be achieved. Many of the assumed control techniques have not been fully demonstrated on operational facilities. Although considerable research is being devoted to these control techniques, and promising results are being obtained, in the end, they must be proven feasible and their actual cost must be on the order assumed for the present analysis to be viable.

It is also very important to realize that the entire analysis assumes there is no difference in the health impacts caused by NO_x emissions from all sources. Considering that mobile sources in urban areas generally are more co-located with the population, the validity of this assumption may be questionable.

5.2.8 ADDITIONAL DISCUSSION OF NO_x EMISSION STANDARDS FOR LDV'S

In the preceeding analysis a baseline case was established assuming that a 2.0 gm/mi NO_x emission standard would be in effect for LDV's by 1980. Since the current NO_x standard for LDV's is 3.1 gm/mi and since several control strategies for stationary sources were found to be more cost-effective than reducing the LDV standard below 2.0 gm/mi, it is prudent to investigate the cost-effectiveness of reducing the LDV NO_x emission standard from 3.1 to 2.0 gm/mi.

For gasoline powered LDV's the 2.0 gm/mi NO_x standard can be obtained through the use of proportional exhaust gas recirculation (PEGR). In Reference 8 the cost for PEGR is estimated to be from $11.00 to $22.00 per automobile. Technology is available which will allow PEGR to be introduced without a penalty in fuel economy and without increasing maintenance costs. Therefore it is assumed that to reduce the NO_x

standard from 3.1 to 2.0 gm/mi, the cost over the life of the car will average approximately \$20.00. If the life of the car is assumed to be 100,000 miles, the cost-effectiveness of reducing the NO_x standard from 3.1 to 2.0 gm/mi can be determined to be \$165./ton of NO_x removed. Comparison of this value with other cost-effective values in Table 5.2 indicates that reducing the LDV NO_x emission standard from 3.1 to 2.0 gm/mi is one of the most cost-effective strategies to NO_x emission reductions. Further, the full effectiveness of this strategy could be realized much sooner than could some of the strategies discussed for stationary sources or the more stringent controls for mobile sources. Finally, results to date from comparisons between 1976 model cars sold in California and elsewhere, confirm the above assumption that manufacturers can produce cars that meet the 2.0 gm/mile standard without a fuel penalty. (see references below)

Austin, T.C., Michael, R. B., and Service, G.R.; "Passenger Car Fuel Economy Trends Through 1976", October, 1975, Society of Automotive Engineers Preprint 750957.

Austin, Thomas C., and Hellman, Karl H.; "Fuel Economy of the 1975 Models", October, 1974, Society of Automotive Engineers Preprint 740970.

Gumbleton, James J., Bolton, Robert A., and Long, H. Walter; "Optimizing Engine Parameters With Exhaust Gas Recirculation; February, 1974, Society of Automotive Engineers, Preprint 740104.

5.3 COST-EFFECTIVENESS IN REDUCING HYDROCARBON EMISSIONS

The methodology used in this section is similar to that described in the previous section involving cost-effectiveness of NO_x control. That is, a cost-effectiveness ratio (in dollars per ton of hydrocarbon removed) is calculated for various levels of control for both stationary and mobile sources, which then can be used to determine the best approach in achieving a given level of control.

5.3.1 BASELINE EMISSIONS

Before a comparative analysis between stationary and mobile sources in the year 2000 can be made, a baseline case needs to be established. Generally, the baseline emission calculations account for control programs that are planned or underway (e.g., SIP emission limitations). Therefore, the control strategies examined in this section are those that go beyond measures presently planned or being implemented.

For light duty vehicles (LDV), the baseline case is established at the level presently required for vehicles sold in California (0.9 gm/mi). Evaporative losses are presently estimated to be 1.8 gm/mi; however, EPA is presently developing standards to reduce this to between 0.6 and 0.2 gm/mi for 1979 vehicles. Therefore, a value of 0.4 gm/mi was assumed for the baseline case.

It is estimated that by 1980 the vehicle miles of travel (VMT) for LDV's will be about 80% of the total VMT in that year, or 9.6×10^{11} miles per year for LDV. Assuming a compound growth rate of 3% for this category, the corresponding VMT in the year 2000 is 1.7×10^{12}. This, together with the emission standard of 0.9 gm/mi (assuming that the average LDV then just meets the standard in the baseline case), gives 1.7×10^6 tons HC/year for exhaust and 0.8×10^6 tons for evaporation.

The weighted average hydrocarbon emission for 1972 light duty trucks (LDT) and gasoline-engine heavy duty vehicles (GHDV) was 6.3 gm/mi (exhaust) and 4.22 gm/mi (evaporation). It is assumed that by 1980, an exhaust standard for LDT will be set at approximately 1.65 gm/mi and for GHDV at 6.0 gm/mi, or a weighted average of 2.9 gm/mi. It is anticipated that the LDV evaporative standard for 1979 vehicles will also be applicable to LDT. No further evaporative controls were assumed between now and 1980 for GHDV.

VMT for LDT and GHDV is estimated to be approximately 2×10^{11} in 1980 and 3.6×10^{11} in 2000 (assuming a 3% growth rate). Baseline emissions in the year 2000 are, therefore, 1.1×10^6 tons (exhaust) and 0.8×10^6 tons (evaporation).

For gasoline-powered off-highway vehicles, hydrocarbon emissions in 1972[15] were estimated to be 1.1 million tons. Assuming a 50% reduction by the year 2000 as a result of technology transfer, and using a 3% growth rate, the emissions will be 1.3×10^6 tons HC/year. Similarly, diesel HDV and "other" (railroads, aircraft, and vessels) will grow from 0.3×10^6 and 0.6×10^6, respectively, to 1.1×10^6 combined.

Table 5-3 shows the distribution of hydrocarbon emissions from all sources in 1972[15]. For the point-source evaporation category, approximately half is estimated to result from refinery storage facilities covered by new source performance standards (NSPS). It is assumed that all such storage facilities will meet the NSPS by 2000 and that the NSPS will reduce the emission factor for petroleum storage to 20% of the current factor. Using these assumptions and applying the compounded growth rate of 3.2% used in Section 2, the baseline emissions in 2000 are 4.4 X 10^6 tons per year for the point source evaporation category.

The gasoline marketing emissions in Table 5-3 are assumed to grow at 3% per year (the same as mobile sources), but the total in the year 2000 is reduced by 40% to account for the projected 40% improvement in gasoline mileage.

Table 5-3 contains about 1.2 million tons attributed to forest fires, agricultural burning, structural fires, and coal refuse fires. It is assumed there will be no growth in these emissions. The area source solid waste emissions are expected to decrease sharply in the near-term as a result of implementation plan regulations. Therefore, it was assumed that this category would be reduced by 50% and that there would be no growth between now and 2000 in this category.

The 1972 inventory shown in Table 5-3 has also been adjusted to eliminate methane emissions, since the air quality standard is set for non-methane hydrocarbons. The major sources of methane included in the 1972 inventory are synthetic ammonia (0.75 million tons) and natural gas combustion (0.15 million tons).

The remaining stationary source emissions not discussed above are assumed to grow at 3.2% per year through the year 2000. The distribution of emissions for the baseline case in the year 2000 is also sum-summarized in Table 5-3.

Table 5-3

Non-Methane Hydrocarbon Emissions in 1972[15]

and Baseline Emissions in 2000 (10^6 tons per year)

	1972	2000
LDV	11.0	2.5
Exhaust		(1.7)
Evaporation		(0.8)
LDT and GHDV	2.3	1.9
Exhaust		(1.1)
Evaporation		(0.8)
Other Mobile	2.0	2.4
Point Source Evaporation	3.0	4.4
Open Fires	1.2	1.2
Area Solid Waste	1.5	0.7
Gasoline Marketing	1.0	1.4
Area Solvent Evaporation	1.6	3.9
Chemical Manufacturing	1.7	4.1
Petroleum Refining	0.9	2.2
Miscellaneous	0.9	2.2
Total	27.1	26.9

The estimate of total HC emission in 2000 is, of course, dependent on the assumed growth rates. The sensitivity is such that a difference of 0.5% in the assumed growth rate for stationary sources leads to a difference of about 0.4 in the multiplier (here 2.42) or about 4 million tons. It should be clear that legislating a further reduction in LDV exhaust emission, from 0.9 to 0.41 gm/mi, will not by itself arrest the trend of the total.

5.3.2 COST-EFFECTIVENESS OF LDV CONTROL

The National Academy of Sciences[8] has estimated that the lifetime costs of reducing HC and CO emissions for LDV using an oxidation catalyst from the 1975 California standards of 0.9 HC/9.0 CO to the statutory standards of 0.41/3.4 will be about $50.00 (including maintenance expense, but excluding inspection fees). The marginal cost is relatively low, since both standards involve the use of a catalyst and there is little difference between a catalyst system that meets 0.9/9.0 and one that meets the 0.41/3.4 standards. Since the two pollutants are reduced jointly by the same technology, it is impossible to allocate the cost. Therefore, it is assumed that the cost is equally divided between each pollutant. The cost-effectiveness ratio is then estimated as follows:

$$\$25.00 \quad \frac{(0.9 - 0.41)\ (100{,}000 \text{ miles})}{(454 \text{ g/lb})\ (2000 \text{ lb/T})} = \$470\text{/T of HC removed.}$$

The aggregate expenditure is close to one-half billion dollars annually in the year 2000.

The NAS analysis shows that automotive diesel engines might be the preferred means of achieving the HC/CO standard provided the NO_x standard is not reduced below 1.0 gm/mi. The well-known fuel economy of the diesel engine allows it to lead the list of solutions for all the standards considered except the statutory standards of 0.41 HC/3.4 CO/0.4 NO_x. For the diesel engine the NAS report asigns zero cost for achieving the reduction in HC from 0.9 to 0.41; the diesel engine has not been included in establishing the \$50.00 lifetime cost.

5.3.3 OTHER MOBILE SOURCES

During the current study, no data on the cost of control for other mobile sources could be obtained. However, it seems reasonable to assume that the same percent emission reduction achieved by reducing LDV z

emissions to 0.41 gm/mi could also be achieved for LDT and GHDV at a cost equivalent to reducing LDV from 0.9 to 0.41 gm/mi. The weighted emission factor for LDT and GHDV that is equivalent to 0.41 gm/mi for LDV is approximately 0.8 gm/mi.

Evaporative controls for GHDV are assumed to achieve a percent reduction equivalent to the 1979 LDV standard of 0.4 gm/mi, but at a 50% greater cost. Since the 1979 LDV evaporative controls are expected to cost only $7.00 per vehicle on the average, the cost-effectiveness of GHDV evaporative control is $18.00/T of HC removed.

Under these assumptions, the potential emission reductions and the associated costs are shown below:

Level of Control	Tons HC Removed	Cost Effectiveness	Total Cost
LDT and GHDV: 2.9 to .8 gm/mi	0.84 X 10^6	$470/T	$395 X 10^6
GHDV Evap: 5.8 to .5 gm/mi	0.58 X 10^6	$18/T	$10 X 10^6

Additional mobile source controls for off-highway vehicles, trains, aircraft, vessels, or diesel trucks were not considered.

5.3.4 COST-EFFECTIVENESS OF STATIONARY SOURCE CONTROLS

5.3.4.1 POINT SOURCE EVAPORATION LOSSES

This category includes individual sources which emit more than 25 tons/year (e.g., dry cleaning, vapor degreasing, surface coating, petroleum product storage, the storage of miscellaneous organic compounds, and graphic arts). Trichloroethylene is the most frequently encountered solvent for vapor degreasing. The bulk of some 600 million pounds sold for vapor degreasing was evaporated into the air in 1972.

The estimated contribution to baseline emissions is 0.73×10^6 tons, of which a part is emitted by area sources. These emissions can be reduced about 40% by temperature controls and housekeeping, at a net savings. Further reduction requires that air flow into the unit when it is open, and that this air be ducted to an automatic adsorption system. Assuming only 90% control, the recovered solvent partially defrays the incremental expense, leaving an incremental cost-effectiveness of about $85.00/ton. The findings are summarized below:

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 40%	0.29×10^6	-$210/T	-$61 X 10^6
41 to 90%	0.36×10^6	$85/T	$31 X 10^6

The bulk of formulations for industrial surface coatings may be described as "oil-based", as opposed to the water-based paints which have a commanding share of the market for retail finishes. As a rule of thumb, about half the weight of an industrial finish is a combination of volatiles. Thus the 400 million gallons of industrial finishes sold in 1970 would weigh about two million tons and give rise to one million tons of hydrocarbons. Although powder- and water-based systems that eliminate the need for solvents are not yet significant, this technology might be economical compared to oil-based systems with severe emission controls. However, it is not clear that such systems can be used in all situations. Therefore, it is assumed that by 2000, seventy-five percent of the industrial finishes will use non-solvent technology at nominal costs, say $10.00/ton, and that control of the remaining twenty-five percent will be by thermal or catalytic oxidation (incineration).

Incineration is assumed also for other HC sources discussed in this section, but only when other control options are not feasible. This is because the auxillary fuel (gas or oil) needed for such systems will probably become increasingly scarce in the future.

As shown in Table 5-4, the cost of incineration varies substantially, depending mainly on the fuel value of the stream to be incinerated and to a lesser degree, on the operating hours and potential for heat recovery.

Table 5-4

COST OF INCINERATION, $/T

	Operating Time		
Concentration	2000	4000	8000 hr/yr
100 ppm	4055[a]	3810	3690
	2430[b]	2090	1920
300 ppm	1305	1220	1185
	765	650	595
1000 ppm	343	318	306
	180	145	129
3000 ppm	65	59	55
	25[c]	14[c]	8[c]

[a] Without heat recuperator.

[b] With optional heat recuperator.

[c] Less unquantified credits for waste heat.

Basis: 10,000 scfm of air at 300°F, containing toluene at the indicated levels: total capital investment of incinerator, $50,000.00 of optional heat exchanger with 50% effectiveness, $20,000.00: annual capital charges, 15%; fuel at $2/MMBtu; no other costs.

For industrial finishing operations, the cost-effectiveness of the two levels of control discussed above are summarized below:

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 75%	1.82×10^6	\$10/T	18.2×10^6
76 to 97%	$.55 \times 10^6$	\$100/T	\$55 $\times 10^6$

Emissions from the graphic arts industry in 1968, when very little emission control was practiced, were estimated to be 550 million pounds for the industry as a whole[16]. After escalation, this source accounts for 0.75 million tons of baseline emissions. Gravure printing accounts for 30% of these emissions. Adsorption would permit 98% recovery or better; the recovered solvent would have substantially the amount, and hence substantially the composition and value, of a solvent otherwise purchased, say \$0.04/lb. The savings can more than pay the carrying charges and other operating costs of the control system.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 98%	0.22×10^6	-\$50/T	-\$11 $\times 10^6$

Letterpress and lithography together account for some 40 percent of these emissions. The volatiles are such that adsorption is inappropriate, but a catalytic afterburner can be used. Heat recovery, except at a few metropolitan newspaper plants, would not be cost effective. Since most operations are small, the cost-effectiveness is relatively high, as shown below.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 90%	0.27×10^6	\$700/T	\$190 $\times 10^6$

It is acknowledged that the handful of large metropolitan newspapers can be controlled at a significantly lower cost, but not less than the fuel cost.

Metal decorating plants account for only about 20% of emissions in the graphic arts. Control techniques are mainly limited to thermal or catalytic oxidation. These are generally large-scale operations and the hydrocarbon stream is more concentrated, making heat exchange practical. The resulting cost-effectiveness is very reasonable.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 90%	0.14×10^6	$150/T	$\$20 \times 10^6$

The remaining 10 percent of the graphic art emissions, arising from flexography, are deemed uncontrollable.

As with industrial surface coatings, there is some progress in the graphic arts away from inks containing 30-75% solvents. Screen printing, especially of textiles, can use water-based formulations. Some inks have reactive monomers in place of volatile dilutents; these are cured in place by heat treatment. However, it is premature to assume that a significant portion of the solvent-based inks can be replaced by non-solvent formulations. Therefore, thermal or catalytic oxidation control techniques have been used in this analysis.

Purchases, and hence presumably emissions, of drycleaning solvents in 1971 were approximately 0.25×10^6 tons, which escalates to 0.60×10^6 tons in 2000. The use of petroleum-based solvents, which are presently poorly controlled, is being phased out in favor of chlorinated solvents. Since the chlorinated solvents are more costly, efficient controls are installed for economic reasons. Therefore, it is assumed that these emissions will be substantially reduced at nominal cost, say $10.00/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 80%	0.48×10^6	$10/T	$\$4.8 \times 10^6$

5.3.4.2. GASOLINE DISTRIBUTION

This item under point sources of evaporation refers to operations at regional marketing terminals and other, more concentrated operations extending back toward the refineries. Losses at filling stations are considered in the next sub-section.

Some 2300 million barrels of gasoline were produced in 1972. Since gasoline is the largest single refinery output and one of the most volatile, it would seem to be responsible for the bulk of the hydrocarbon emissions from the manufacture, distribution, and sale of petroleum products. The emission factor for splash loading of tank trucks is 12.4 lb/1000 gal[17], giving 0.56 million tons of emissions. This, escalated at 3.2% compounded, accounts for 1.35 million tons of baseline emissions. The emission factor for submerged loading is only 4.1 lb/1000 gal, a reduction of 67% at nominal expense. Substantially complete elimination of losses is expected from the use of adsorption or refrigeration systems to remove gasoline from the air displaced from the tank truck during loading at the terminal. For a typical terminal handling 250,000 gallons per day, already practicing submerged loading, an investment of $235,000 and annualized costs of perhaps $50,000 are required[18]. This provides an incremental cost-effectiveness of $270/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 67%	0.91×10^6	0	0
67 to 99%	0.43×10^6	$270/T	$115 \times 10^6

5.3.4.3 GASOLINE HANDLING

This item pertains to the area sources made up of the multiplicity filling station operations serving all kinds of gasoline powered vehicles. Uncontrolled emissions, in lb/1000 gallons handled, are as follows: (1) unloading (i.e., evaporation into the air drawn into the tank truck at delivery)--2.1; (2) splash loading the underground tank--11.5; (3) unloading the underground tank--1.0; (4) filling the vehicle tank--11.0; and (5) spillage--0.67. It is assumed that the baseline emissions account for submerged filling of underground tanks, which reduces total emissions by 16% from the uncontrolled situation. Baseline emissions in 2000 were calculated above to be 1.4×10^6 tons.

Tank truck unloading and underground tank filling losses can be reduced by 95% by recycling the air displaced from the underground tank to the tank truck. The required investment consists of special pipes and hoses on each tank truck and special fittings on the tank fill pipes. For a model terminal handling 250,000 gallons per day and serving 300 stations handling 25,000 gallons per month, the estimated investment is $320,000[18] and the annual cost about $60,000. The cost-effectiveness of this strategy, commonly called Stage I control, is $100.00/T and increases overall control of gasoline handling emissions from 16% to 50%.

Further controls, referred to as Stage II controls, can be applied to the vehicle tank filling operation, utilizing either a vapor balance system, which returns displaced vapors to the underground tank, or a vacuum assist system, which incorporates a mechanism for condensing or incinerating the displaced vapors. If intermediate size stations

(120,000 - 360,000 gallons throughput per year) use the vapor balance system and large stations (greater than 360,000 gallons) use the vacuum assist system, overall control of items (3) and (4) above is expected to be about 85% at a cost for both size stations of approximately $0.38 per gallon of throughput. These figures include exempting small stations (less than 120,000 gal/yr throughput) from control, since these account for only 9% of the total gasoline pumped. It is also estimated that these systems, in conjunction with improved operating practices, can reduce spillage emissions by 83%. This strategy increases overall control of gasoline handling emissions from 50% to 91%, at a cost-effectiveness of $700.00/T. The cost-effectiveness of these levels of control is summarized below:

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
16 to 50%	.57 X 10^6	$100/T	$57 X 10^6
51 to 91%	.68 X 10^6	$700/T	$475 X 10^6

5.3.4.4 AREA SOURCE EVAPORATION

This category includes numerous small sources which are not identified individually for emission inventory purposes. Several of the control strategies discussed in the "Point Source Evaporation" category affect emissions that are part of the "Area Evaporation" category in Table 5-3 (e.g., smaller dry cleaning, degreasing, and industrial finishing operations). The only source category not already treated which can reasonably be controlled is architectural coatings. Although water-based coatings constitute a substantial portion of the trade sales market, 1970 emissions from oil-based finishes were approximately 0.4 X 10^6 tons. This would increase to 1.0 X 10^6 in 2000 at a 3.2% growth rate. It is assumed that further improvements in water-based coatings in conjunction with necessary regulatory action will totally eliminate hydrocarbon emissions from architectural coatings by the year 2000 at nominal costs, say $15.00/Ton.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 100%	1.0 X 10^6	$15/T	$15 X 10^6

5.3.4.5 SOLID WASTE AND OPEN FIRES

No further control of solid waste emissions beyond the measures used in calculating the baseline emissions were considered feasible. In sparsely populated areas, collection and land fill or municipal incineration is not a practical alternative to open burning.

Similarly, emissions from agricultural burning and forest fires are largely rural. However, there are measures that can be, and are being taken to reduce these emissions, or at least reduce their air quality impact. Some states have instituted programs which allow agricultural and forest management burning only on days of favorable meteorological conditions. Although this does not actually reduce emissions, some partial credit can be given as a result of its favorable impact on air quality. Also, efforts are being devoted to developing mechanical harvesting methods which would eliminate the need to burn-off sugar cane and pineapple fields. It is assumed that the aggregate effects of these measures would be to reduce the baseline emissions by 25% at nominal cost, say $20.00/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 25%	0.3×10^6	\$20/T	\$6 X 10^6

5.3.4.6 CHEMICAL MANUFACTURING

Acrylonitrile is an important organic intermediate, employed almost exclusively for acrylic fibers. Present emissions are estimated to be 330 lb/ton of product. A new catalyst with improved conversion has achieved a 35% reduction to 210 lb/ton. Further control can be accomplished through thermal incineration, at an estimated cost of \$37.00/ton[19]. The 1974 production was 720,000 tons, which is expected to increase to 1.63 million tons by 2000. The cost-effectiveness for these two levels of control are:

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 35%	0.095×10^6	0	0
36 to 99%	0.173×10^6	\$37/T	\$6.4 X 10^6

Non-methane hydrocarbons from carbon black production amount to 70 lb/ton[19], and annual production is currently some 1.8 million tons. Thus uncontrolled emissions amount to 0.063 million tons, escalating to 0.15 million tons of the baseline total. Control schemes involving incineration with waste-heat recovery are feasible for new plants, achieving substantially complete control at nominal expense, say \$10./T. Retrofits are more difficult but, it is assumed that all existing plants will have been replaced by 2000.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 95%	0.14×10^6	\$10/T	\$1.4 X 10^6

Present emissions from the manufacture of polyethylene are about 0.08 million tons of non-methane hydrocarbons, escalating to about 0.2 million tons in 2000. The emissions can be flared or piped to a waste-heat boiler; fuel credits in the latter case balance capital charges.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 95%	0.19×10^6	0	0

Ethylene oxide is an important end use for ethylene and a valuable intermediate, produced in 1972 at a scale of 2.4 million tons. When this material is made by air oxidation of ethylene, the nitrogen must be released and with it an estimated 220 lb HC/ton of product[19]. When the product is made with oxygen instead of air, emissions are minimal. Since this technology is already practiced and presumably competitive, it is assumed that all ethylene oxide will be so produced by 2000 at minimal expense, say $20.00/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 100%	0.44×10^6	$20/T	$\$8.8 \times 10^6$

Cyclohexanone (plus cyclohexanol) and terephthalic acid both involve the air oxidation of liquid hydrocarbons in the presence of a catalyst. Nitrogen must be vented. The hydrocarbon emissions total 0.08 million tons, escalating to 0.2 million tons of the baseline. It is conceivable that emissions could be reduced by using oxygen instead of air, as in the case of ethylene oxide. For the moment, however, we assume that vent losses would be reduced by condensation, scrubbing with a cycle oil, or incineration. In the latter case, the large scale, quasi-continuous operation, and fuel value suggest a control cost of about $120/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 95%	0.19×10^6	\$120/T	\$23 $\times 10^6$

Formaldehyde is similarly produced by air oxidation of methanol in the vapor phase over a catalyst. Emissions of non-methane hydrocarbons amount to about 0.025 million tons, escalating to 0.06 million tons in 2000. Incineration with heat recovery would be appropriate, since the stream is relatively rich in hydrogen; this control is already incorporated in one plant and should become the standard at modest cost, say $10.00/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 95%	0.06×10^6	\$10/T	\$0.6 $\times 10^6$

Hydrocarbon emissions from the preparation of charcoal are 480 lb per ton of product[17], or 0.14 million tons in 1972, escalating to 0.34 million tons of baseline emissions. The volatiles are combustible whether or not recovery of by-products such as wood alcohol (methanol) is practiced. Auxiliary fuel is not required and, if anything, there should be credits for by-product heat. A flare is appropriate on the small scale. Therefore, it is assumed that emissions can be reduced by 99% at no net cost, or even perhaps a marginal profit.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 99%	0.34×10^6	0	0

In the manufacture of paint and varnish, resin vehicles are cooked and blended with pigments, solvents, and diluents. Fugitive emissions of solvent vapors and cooking by-products are common, but proper hooding, dampers, and control systems should collect a relatively rich contaminant stream for incineration at a cost of \$50.00/T. Fugitive emissions may still amount to 30%, but nearly complete control of the remainder is feasible. Emissions in 1972 are estimated at .05 X 10^6 tons, which increase to 0.12 X 10^6 tons in 2000.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 70%	0.09 X 10^6	\$50/T	\$4.5 X 10^6

Ethylene dichloride, an intermediate leading to vinyl chloride, is produced by heating ethylene, hydrogen chloride, and air in the presence of a catalyst. This product is easily condensed, but the exhaust nitrogen carries ethylene and other hydrocarbons. Emissions in 1972 from this major polluting process were approximately 0.07 million tons, escalating to 0.17 million tons in 2000. A waste-heat-boiler with caustic scrubbing to remove hydrogen chloride from the stack gas achieves substantial control at modest cost.[19]

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 95%	0.16 X 10^6	\$40/T	\$6.4 X 10^6

The 1972 emissions of the major source categories discussed above total about one million tons, as compared with the 1.7 million tons shown in Table 5-3 for the chemical manufacturing industry. The remaining 0.7 million tons, which escalate to 1.7 million tons in 2000, come from a multitude of smaller sources which will be handled in the aggregate. It is assumed that 0.8 million tons are uncontrollable; 0.6 million tons can be incinerated, with fuel credits balancing capital charges, and the remaining 0.3 million tons can be controlled by incineration at an average cost-effectiveness of $200/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 35%	0.6×10^6	0	0
36 to 53%	0.3×10^6	$200/T	$60 X 10^6

5.3.4.7 PETROLEUM INDUSTRY

Table 5-3 shows 1972 emissions to be 0.94 million tons, which escalates to 2.29 million tons in the year 2000.

The process heaters, steam boilers, and miscellaneous fires in a refinery consume about five per cent of the fuel value of the crude. Much of this fuel is gas, but to be conservative it is assumed that all fuel is residual oil with an emission factor of 140 lb HC/1000 bbl. The 1972 aggregate crude run of some 5000 million barrels required the burning of about 250 million barrels, generating at most 18,000 tons of hydrocarbons. Since this is so small in comparison with the total national emissions, no controls were assumed.

Miscellaneous sources such as valve stems, pipe flanges, and compressor seals, aggregated with controlled emissions from blow-downs, amount to 76 lb/1000 bbl crude run, for a total of about 180,000 tons of HC. Escalating to 2000, this category accounts for about 0.45 million tons in baseline emissions. It is difficult to quantify either reductions or costs in this category. New construction might embrace packless valves and improved compressor seals. It is estimated that fugitive emissions could be cut in half by improved housekeeping at modest cost, say $20.00/T. This reduction represents about 10% of the total refinery emissions.

Catalytic cracking also accounts for significant hydrocarbon emissions. The larger, continuous types characteristic of new construction will be required to have waste-heat boilers as a result of NSPS for CO emissions. The feed to catalytic cracking is 20-50% of the volume of crude run, say 2000 million barrels; the emission factor for uncontrolled units, 220 lb/1000 bbl, leads to 0.22 million tons which would escalate to 0.53 million tons in 2000. This amount, which represents about 23% of the total refinery emissions in 2000, will be almost entirely controlled at a savings.

The foregoing has described sources which are universally found in petroleum refineries. However, there are processing features which make every refinery unique and which cannot be dealt with in the aggregate.

To the extent that these emissions may be captured, they can be piped to a flare, a process heater, or a waste-heat-boiler; to the extent that they are fugitive, they must be reduced by monitoring and housekeeping. 50% control of the remaining emission is assumed at a cost of \$20.00/T. This provides an additional 33% control of total refinery emissions in the year 2000. The total of the above control measures is 67%.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 67%	1.53 X 10^6	\$13/T	\$19.6 X 10^6

5.3.4.8 OTHER STATIONARY SOURCES

Fuel burning, in the aggregate, accounts for 0.47 million tons in the 1972 inventory and this escalates to 1.14 million tons of baseline emissions. Although increasing fuel prices will probably result in some increase in combustion efficiencies, it is assumed that there is little margin for improvement in this category.

Hydrocarbon emissions from coke ovens in 1972 are estimated at 0.12 X 10^6 tons, which escalates to 0.3 X 10^6 tons in the year 2000. NSPS for particulate matter from coke ovens are being developed; however, substantial control of hydrocarbons (perhaps 80%) will also result. Allocating half of the estimated cost of $1.26 per ton of coke to each pollutant, the cost-effectiveness is $435/T.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 80%	0.24 X 10^6	$435/T	$105 X 10^6

Foundries use molds made of sand or other minerals bonded together by small amounts of natural or synthetic resins. The resin must be heat cured, giving off various hydrocarbon compounds. One estimate[20] of 1975 emissions is 0.11 million tons, escalating to 0.24 million in 2000. With attention to housekeeping and charging rates this process could be made more stable and amenable to condensation of resinuous by-products with value as a fuel, as in by-product coking. The remainder would be a low-Btu gas, also suitable as fuel. This technology is more likely to be cost- effective at the large scale than in the job shop. Costs are conjectural.

Control	Tons HC Removed	Cost-Effectiveness	Total Cost
0 to 60%	0.15×10^6	\$500/T	$\$75 \times 10^6$

5.3.5 COST-EFFECTIVENESS RANKING

The results of the foregoing analyses are displayed in Table 5-5 in the order of cost-effectiveness; i.e., unit cost per ton of HC removed. The table enumerates means of reducing non-methane HC emisions 55% below the year 2000 baseline of 26.9 million tons, to 11.8 million tons. By contrast, 1972 non-methane HC emissions were 27.1 million tons. Thus, on a nationwide scale, the hydrocarbon (and accordingly the oxidant) picture can be dramatically improved at a cost estimated at two billion dollars annually in 1975 dollars. Implementation of all strategies shown in Table 5-5 will require approximately a 75% increase in the control of stationary source HC emissions as compared to the current level of control.

It should be recognized that the percentage reduction obtainable through each of the measures shown in Table 5-5 will vary considerably from city-to-city, depending on the distribution of sources in each city and the controls that may have already been applied. Also, it is clear from the high degree of emission reduction needed to attain the national standard for oxidants in many cities[1], that implementation of all measures shown in Table 5-5 will still not result in attainment of the oxidant standard.

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Table 5-5

COST-EFFECTIVENESS OF HC CONTROLS

Control (%)	HC Removed (millions of tons)	Percentage of Baseline	Cumulative % of baseline	Incr. Cost ($/T)	Annual Cost (millions of $)	Cumulative (millions of $)
Degreasing 0-40	0.30	1.1	1.1	-210	-61	-61
Gravure 0-98	0.22	0.8	1.9	-50	-11	-72
Gas Terminal 0-67	0.91	3.4	5.2	0	0	-72
Acrylonitrile 0-35	0.10	.5	5.5	0	0	-72
Polyethylene 0-95	0.19	.7	6.2	0	0	-72
Charcoal 0-99	0.34	1.2	7.4	0	0	-72
Miscellaneous Chemicals 0-35	0.60	2.2	9.6	0	0	-72
Dry Cleaning 0-80	0.48	1.7	11.3	10	5	-67
Industrial Finishing 0-75	1.82	6.8	17.8	10	18	-49
Carbon Black 0-95	0.14	.5	18.3	10	1	-48
Formaldehyde 0-95	0.06	.2	18.5	10	1	-47
Refining 0-67	1.53	5.7	24.0	13	20	-27
Arch. Coatings 0-100	1.00	3.7	27.6	15	15	-12
GHDV Evap. 5.8 - 0.5 gm/mi	0.58	2.1	29.7	18	10	- 2
Open Burning 0-25	0.30	1.1	30.8	20	6	4
Ethylene Oxide 0-95	0.44	1.6	32.4	20	9	13
Acrylonitrile 36-99	0.17	0.6	33.0	37	6	19
Ethylene Dichloride 0-95	0.16	0.6	33.6	40	6	25
Paint & Varnish 0-70	0.09	0.3	33.9	50	5	30
Degreasing 41-90	0.36	1.3	35.2	85	31	61
Industrial Finishing 76-97	0.55	2.0	37.2	100	55	116
Gasoline Handling 16-50	0.57	2.0	39.2	100	57	173
Cyclohexanone 0-95	0.19	0.7	39.9	120	23	196
Metal Decorating 0-90	0.14	0.5	40.4	150	20	216
Miscellaneous Chemicals 35-53	0.30	1.1	41.5	200	60	276
Gasoline Distribution 67-99	0.43	1.5	43.0	270	115	391
Coke Ovens 0-80	0.24	.9	43.9	435	105	496
LDV Exhaust 0.9 - 0.41 gm/mi	0.93	3.5	47.2	470	440	936
LDT & GHDV Exhaust 2.9 - 0.8 gm/mi	0.84	3.1	50.2	470	395	1330
Foundries 0-60	0.15	0.5	50.7	500	75	1410
Letterpress & Lithography 0-90	0.27	1.0	51.7	700	190	1600
Gas Handling 51-91	0.68	2.5	54.1	700	475	2080

5.4 COST-EFFECTIVENESS IN REDUCING CARBON MONOXIDE

Since elevated ambient concentrations of CO are overwhelmingly due to mobile sources, there is little to be gained by considering mobile source versus stationary source tradeoffs. Based on 26 cities considered in a recent EPA analysis (Reference 1), the average stationary source contribution to the CO problem in 1970 was only 2%. This figure includes an adjustment to the emission inventory to reflect the relative contribution of stationary and mobile sources to ground level air quality. If the statutory LDV standard for CO is imposed in 1978, the average stationary source contribution will rise to 11% in 1985. It may be more productive to consider the tradeoffs between LDV emissions and other mobile source emissions, although this is not within the scope of this section. For example, the average contribution of other mobile sources is 26% in 1970 and rises to 52% in 1985 (assuming the statutory LDV standard is implemented in 1978 and no new emission control programs are instituted for the "other mobile source" category).

5.5 FEASIBILITY OF TWO-CAR STRATEGY

In order to assess the feasibility of a two-car strategy it is first necessary to determine the fraction of new car sales which would require stringent vehicle controls. A rough approximation of this figure can be based on a listing of those Air Quality Control Regions (AQCR's) with existing or potential air quality problems. It appears reasonable to conclude that the 26 AQCR's which will not attain the national NO_2 standard by 1980 (see Section 3.1.3.3) should be affected by the more stringent controls of any two-car strategy. These AQCR's had a 1970 population of approximately 93,000,000 (out of a total U.S. population of about 200,000,000) and are located in 26 States. Assuming that car sales are proportional to population, a two-car strategy would require at least half of the new cars to meet the more stringent emission limitation. By comparison, the present two-car strategy, which applies only in California, requires only 11% of the new car sales to meet lower emission standards.

The number of vehicles requiring more stringent controls for CO appears to be about the same as for NO_2, since 29 AQCR's are expected to exceed the national standard for CO in 1980 (see Section 3.1.3.3). For oxidants, however, where the number of AQCR's exceeding the national standard in 1980 is expected to be at least 72, and probably more, the more stringent controls of a two-car strategy would need to be applicable to the vast majority of cars sold in the U.S., thereby eliminating most, if not all, of the cost savings of a two-car strategy.

Recent studies have showed that oxidant concentrations in rural areas are as high or higher than oxidants in urban areas. The reasons for this and the implications for a national control strategy are discussed in Reference 21. One of the principal conclusions is that there is a need for hydrocarbon control over wide geographic areas if standards are to be met in non-urban areas. Given the ubiquitous nature of the oxidant problem, a two-car strategy does not appear feasible with respect to hydrocarbons and oxidants.

A detailed study of the feasibility of a two-car strategy, entitled "Examination of Issues Related to Two-Car Regional Emission Control Strategies," was prepared for EPA by the Aerospace Corporation in April 1973. Although this report dealt with a two-car strategy for CO and hydrocarbons, most of the problems identified for such a strategy are also applicable in relation to NO_x emissions. Some of these problems are discussed below:

1. Car manufacturers were generally opposed to a two-car strategy which goes beyond the present California-only strategy, primarily on the basis of assembly, distribution, and marketing difficulties. Additional assembly plants would have to be converted and cross-shipping of cars might be required (at additional consumer expense).

2. Two classes of cars can be marketed and serviced; however, there is a major impact on the ability to do so resulting from the number of control regions involved. The California-only strategy, with the exception of catalyst-system-unique parts storage and service require-

ments, has been in effect since 1966 with marketing and servicing groups set up to handle the California region and, again, is not unusual. The California-plus strategy may be highly disruptive for distribution, sales, and service channels unless the additional areas are sufficiently large. Although not an impossible task, it could be very difficult to provide a full model mix of new cars and adequate service to all cities potentially involved in such a strategy. The degree of difficulty, of course, increases as control areas are added.

3. Benefits claimed for the California-only strategy by the auto industry are primarily economic in nature (e.g., more learning time, lessened assembly-line impact, warranty-recall cost statistics accumulated at limited risk, etc.). The companies also feel that service, parts distribution, and training can be more thoroughly accomplished and evaluated in a limited area.

4. The principal impact on the purchaser of a low-emission car in the control region is economic in nature. In addition to the higher purchase price (unless cost increases are spread over all cars), the owner of a low-emission car is subject to the loss of the extra cost of the low-emission system on resale if sold outside of the control region. Also, if higher-emission cars were permitted into control regions, as used cars without retrofit, such cars could undersell the low-emission cars. This could create a strong demand within the control region for higher-emission used cars from outside the region, and make the resale of low-emission cars difficult.

5. Owners of low-emission cars may encounter difficulties in obtaining replacement parts if problems develop on trips outside the control region (24 hours delays are likely in some cases), and service in such areas from mechanics with little or no experience on the low-emission system may be of poor quality.

6. Any requirement to retrofit higher-emission model cars with low-emission vehicle control systems would be severe. It may be physically possible, but it would be economically impractical unless both emission control systems were essentially the same except for a catalytic converter. This means that retrofit to factory-installed system features and performance levels has to be planned prior to production commencement.

7. Most states foresee many problems in administering the two-car strategy, if it were based on regional control within a state; on that basis, statewide control would be generally preferred. On the other hand, since many of the states have their automotive pollution problems concentrated in a single AQCR, they also foresee many objections to having stringent control implemented outside those areas. If price differences between low-emission and high-emission cars were large, the problems associated with a statewide control strategy would be accentuated. If the two-car strategy were instituted on a statewide basis in the 26 states with existing or potential NO_2 problems, the fraction of new car sales affected by the more stringent emission controls would rise to 74%.

8. California is the only state that has existing procedures for administering a car control program to standards other than Federal nation-wide emission standards. California presently has an assembly-line inspection program and requires a certificate of compliance with California emission standards as a condition to sale and registration of new cars sold in that state. Also, California's size, population distribution, and natural borders tend to enhance two-car strategy control feasibility.

9. All states (including California) lack the ability to strictly enforce the two-car strategy on a 100 percent compliance basis. There are numerous loopholes in existing registration laws (lack of verification of vehicle domicile, "used-car" provisions, etc.) as well as fleet-sale (sold in one state, delivered and used in another) and border dealer problems.

In summary, it would appear that the benefits of a two-car strategy that allows a small percentage of the new cars to meet a less stringent emission limitation (assuming statewide application of the strategy) would be outweighed by the problems that would affect auto manufacturers, consumers, and control officials as a result of such a strategy.

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6.0 Noise

6.1 LEGISLATIVE MANDATE

Federal noise legislation first appeared in 1968 when Congress directed the FAA to establish rules and regulations to control aircraft noise. The Clean Air Amendments of 1970 called for the establishment of an Office of Noise Abatement and Control in EPA. The legislation also called for public hearings on environmental noise and a special report to the Congress on the problem, incorporating the results of the public hearings and other special studies. Information from this EPA report as well as extensive Congressional hearings formed the basis of the Noise Control Act of 1972.

The Noise Control Act of 1972 (Public Law 92-754, 86 Stat. 1234) represents a comprehensive Federal attempt to set standards and regulations to abate and control noise. It is preventive noise control legislation intended to address an emerging problem.

The Noise Control Act of 1972 established, by statutory mandate, a national policy to control the emission of noise detrimental to the human environment. Findings and policy are described in Section 2 of the Act:

"Sec. 2. (a) The Congress finds—

(1) that inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas;

(2) that the major sources of noise include transportation vehicles and equipment, machinery, appliances, and other products in commerce; and

(3) that, while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce, control of which require national uniformity of treatment.

(b) The Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare. To that end, it is the purpose of this Act to establish a means for effective coordination of Federal research and activities in noise control, to authorize the establishment of Federal noise emission standards for products distributed in commerce, and to provide information to the public respecting the noise emission and noise reduction characteristics of such products."

The Act provides for a division of powers between the Federal, State and local governments in which the primary Federal responsibility is for noise source emission control. The States and other political subdivisions retain rights and authorities to establish and enforce controls on environmental noise through licensing, regulation or restriction of the use, operation, or movement of noise sources and on the levels of noise permitted in their environments. In the near term, the legislative mandate prescribed mandatory deadlines and priority emphasis by EPA on the regulation of products based on the application of best available technology. In the long term increasing emphasis was projected for Federal assistance to State and local governments, enforcement and research.

6.2 Effects of Noise

Noise, defined here as unwanted sound, is considered to be an environmental pollutant, a waste product generated from man's activities. Environmental noise is growing to the point where it is becoming a threat to our health and welfare. While long exposure to high levels of noise is recognized as a principal cause of hearing damage, lower levels of intermittent noise have been found to produce anxiety and distress. These latter effects include interference with speech communication, telephone communication, listening to television and radio, concentration during mental activity and the performance of tasks, and sleep and relaxation.[1]

Since the passage of the Noise Control Act of 1972 considerable progress has been made in defining the nation's noise problem and formulating policies to cope with it. Information regarding the levels of environmental noise requisite to protect the public health and welfare is provided in the EPA Levels Document.[2]

The phrase "public health and welfare effects," as used in the Noise Control Act and herein, includes personal comfort and well-being as well as the absence of mental anguish and annoyance.

The cohesive terminology "health and welfare" refers not only to the direct effects of noise (e.g., hearing loss) but also refers to other indirect effects as well, such as annoyance, communication interference, non-auditory consequences, sleep disruption, etc. Furthermore, the Noise Control Act of 1972 does not permit dissectioning of the phrase in that "primary" and "secondary" effects are not identified in that legislation.[3]

The criteria developed to identify products which are major sources of noise and for which noise emission standards are requisite to protect public health and welfare, stipulate that priority must be given to products that contribute to community noise exposure. Community noise exposure is that exposure experienced by the community as a whole as a result of the operation of a product as opposed to that exposure experienced by the user(s) of the product.

To analyze the effects of noise, a statistical approach is adopted to determine the order of magnitude of the population that may be affected. To perform the analysis of noise impact, a noise measure is utilized that condenses the information contained in the noise environment into a simple indicator of quantity and quality which correlates well with the overall long-term effects of noise on the public health and welfare. This noise measure, the day-night average sound level[2], Ldn, is believed most useful for describing environmental noise and its effect on people, independent of the source of the noise. Hence, noise, whether produced by motor vehicles, aircraft, or industrial facilities, is evaluated on the basis of a common measure of noise. (Definition and computation of Ldn is explained in Appendix A.)

In the following sections, the measures used to evaluate environmental noise, the numerical values of noise levels to consider in assessing impact, and a general methodology for quantifying the noise impact of any noise producing system being added to the environment, or the impact of a change in an existing noise producing system are addressed.

6.2.1. History

Various studies have shown the major sources of outdoor noise in urban residential areas to be motor vehicles, aircraft and voices. This conclusion was best summarized by a survey[4] of 1200 people, the results of which are presented in Table6-1 (Note: The reported percentages do not add to 100%).

Table6-2 shows that traffic noise was a major contributor to noise related dislikes. When queried further, it was revealed that 62 percent of the sample were bothered by at least one sound, and expressed more specific disturbances which are tabulated in Table 6-3.

TABLE 6-1
PERCENT CONTRIBUTION OF EACH SOURCE IDENTIFIED BY RESPONDENTS CLASSIFYING THEIR NEIGHBORHOOD AS NOISY
(72% of 1200 RESPONDENTS)[4]

Source	Percentage
Motor Vehicles	55
Aircraft	15
Voices	12
Radio and TV Sets	2
Home Maintenance Equipment	2
Construction	1
Industrial	1
Other Noises	6
Not Ascertained	8

Hearing Loss

It is well established that noise exposure of sufficient intensity and duration can produce hearing damage. A considerable amount of hearing loss data have been collected and analyzed. These data include measurements of hearing loss in people with known histories of noise exposure.[2]

The EPA has identified an Leq(8) of 75 dB (corresponding to an Leq(24)of 70) as the noise level below which hearing damage will not occur (see Appendix A for an explanation of Leq).

TABLE 6-2

THE ONE SOUND WHICH MOST BOTHERS PEOPLE AT HOME, OUTDOORS AND AT WORK[5]

DESCRIPTION OF SOUND	THE ONE SOUND WHICH BOTHERS PEOPLE MOST -		
	AT HOME	OUTDOORS	AT WORK
	%	%	%
Road traffic	22	6	2
Aircraft	5	1	0
Trains	2	0	-
Industrial/Constructional sounds	3	1	3
Domestic/Light appliances	1	-	1
Neighbours' impact noises	3	-	-
Children	4	0	0
Adults' voices	4	0	1
Wireless/T.V.	3	0	0
Bells/Alarms	1	0	0
Pets	1	0	-
Other sounds	0	-	-
Total sounds which bother most people	49	8	7
Individuals			
Those who are bothered by sounds	56	27	20
Those who notice but are not bothered by sound	41	64	70
Those who do not notice sounds	3	9	10
Base:	100	100	100
No. of individuals	1377	1377	832

TABLE 6-3
SPECIFIC EFFECTS OF NOISE[5]
AS REPORTED BY PERCENTAGE OF COMPLAINANTS

Effect	Yes
Startle	40%
Keep from going to sleep	37%
Wakes up	42%
Interferes with listening to television and radio	39%
Interferes with conversation	35%
Disturbs rest or relaxation	52%
Interferes with other activities	11%
Bothers, annoys, or disturbs in other ways	18%
Makes the house vibrate or shake (aircraft, traffic, and impact noise only)	39%

Since cumulative noise exposure from urban traffic is generally below Leq(24) of 70 dB, it is generally believed that traffic noise is not a significant contributor to hearing damage. This thesis is further supported by the fact that most people who suffer long neighborhood exposure to traffic noise are generally indoors for a portion of the day and thus have the benefit of 10 to 15 dB of noise attenuation from typical building materials.

A 100 site residential area noise survey made for EPA indicates that traffic noise situations causing frequent L_{eq} (24) in excess of 75 dB(A) in such areas are unusual.[6] However, traffic noise may be a significant contributor to hearing loss in those special cases where a person experiences a severe exposure, such as occupational noise, and is also exposed to substantial additional noise from traffic during non-working hours such as commuting to and from work and continuing high levels in his neighborhood. There are presently no data available on the extensiveness of such problems from combined exposures.

Annoyance

Environmental noise interferes with an extensive range of human activity. The effect of such activity interference is usually described as annoyance, which is a psychosocial response to an auditory experience. Annoyance has its roots in the unpleasant nature of some sounds, in the ongoing activities disturbed or disrupted by noise, in the physiological reactions to noise, and the messages conveyed by the sounds as well as prior experiences and conditioning. Many studies have shown that excessive noise reduces one's feeling of well-being, thereby causing anxiety. Excessive noise on a regular, unrelenting basis can jeopardize physical and mental welfare.

The effect of noise on the performance of tasks or activities are often conceptualized in terms of arousal and distraction. Arousal by noise can result in range of detrimental effects on human performance, depending on the nature of the task and the person's state prior to exposure. For instance, noise might induce muscular tension that could interfere with needed delicate movements or prevent needed physical relaxation. Distraction by noise can be considered as a lapse in attention or a diversion of attention from the task being performed, and is usually attributed to the annoying characteristics of noise.

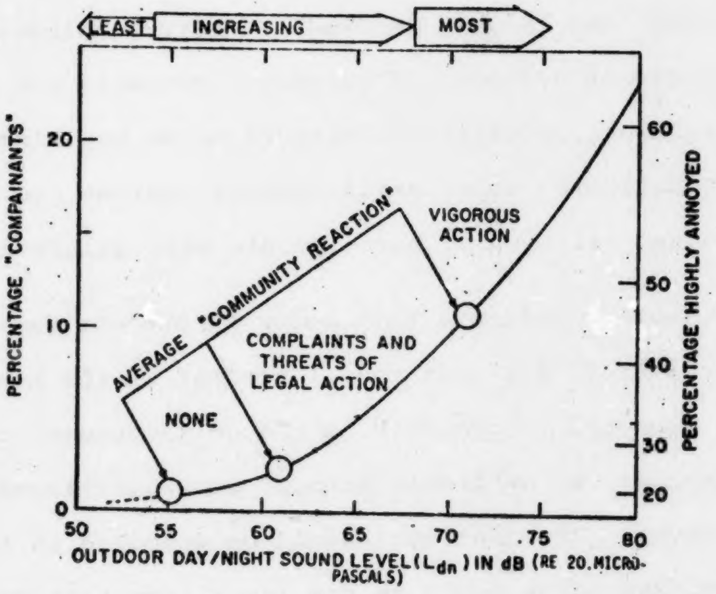
Individuals vary in their tolerance to noise annoyances. The degree of annoyance and whether annoyance leads to complaints or produces rejection of or action against a noise source are dependent on many factors, both scientific and subjective.

Numerous techniques have been developed to measure noise annoyance, ranging from simple scaling involving categories of "not annoyed" and "highly annoyed" to very complicated techniques involving social surveys. Figures 6-1 presents the results of several studies, primarily of airport noise but also includes some information on other environmental sources, to show the dose response relation of noise people will tolerate.

The results indicate that below an outdoor day-night (Ldn) sound level of 55 dB, less than 1 percent of the households would be expected to complain, although 17 percent of the people may respond as highly annoyed when questioned in a social survey. "No reaction" would be expected in the average community, and noise would be the least important factor in attitudes towards the neighborhood. When the outdoor Ldn is 60 dB, approximately 2 percent of the households might be expected to complain, although 23 percent of the people may respond as highly annoyed when questioned, and some reaction would be expected from an average community. If the levels increase over 65 dB, more than 5 percent may be expected to complain, and over 33 percent would respond as highly annoyed. Increasingly, vigorous community reaction could be expected, and noise becomes the dominant factor in disliking an area.

FIGURE 6-1

Summary of Annoyance Survey and Community Reaction Results[2]



Laboratory studies of individual response to noise have helped isolate a number of factors contributing to annoyance, such as the intensity level, tonal characteristics, duration, and degree of interference with activity. It appears that undue interference with activity and annoyance will not occur if outdoor levels are maintained at a day-night average sound level (Ldn) of 55 dB(A) or indoor levels at 45 dB(A).

Communication

One of the most obvious effects of traffic noise is interference with communication. The degree of interference is a function of the type of communication, the conditions under which communication must be maintained, the noise levels, and the frequency spectrum and time pattern of noise.

Noise levels that are not intense enough to cause hearing damage may still disrupt speech communication or interfere with the enjoyment of music or television. Also, interference with the ability to hear warning shouts or commands increases the probability of accidents. The relationships of different noise levels on communications among people is shown in Figure 6-2. The ordinate is the A-weighted sound level of the noise at the listener's ears. The abscissa is the distance between talker and listener in feet, plotted in a logarithmic fashion. The four dashed lines indicate the highest noise level that will permit near-100 percent understanding of sentences spoken with the effort indicated on each curve, in the outdoor environment. Thus, in a 70 dB(A) noise, a normal voice can be heard at a distance of only 2 feet, a raised voice at 3.5 feet, a very loud voice at 7 feet, and a shout at 15 feet. The curve farthest to the left indicates that in 70 dB(A) outdoor noise, speech at the level that is generated when people are engaged in "relaxed conversation" in quiet would be completely understandable only at a distance of 9 inches or so. Beyond 15 feet, progressively more and more of even shouted speech is masked, so that at 70 feet a shout may serve to attract a listener's attention, but will convey little other information.[7]

Sleep

There exists substantial evidence that noise may interfere with sleep.[7] At high levels, noise may arouse a person from sleep, and/or prevent the person from falling asleep. At sub-arousal levels, noise may shift a person's sleep from a deep, dreamless stage to a lighter stage of sleep. The effects of acoustic stimulation on sleep depend upon several factors including the nature of stimulus, the stage of sleep, the familiarity of the person sleeping to the noise source, and various individual differences, e.g., sex, age, physical condition, etc. The likelihood of noise interference with sleep is greatly dependent upon the noise level.[7] Studies have indicated that the adverse effect on sleep becomes increasingly apparent as ambient noise levels exceed about

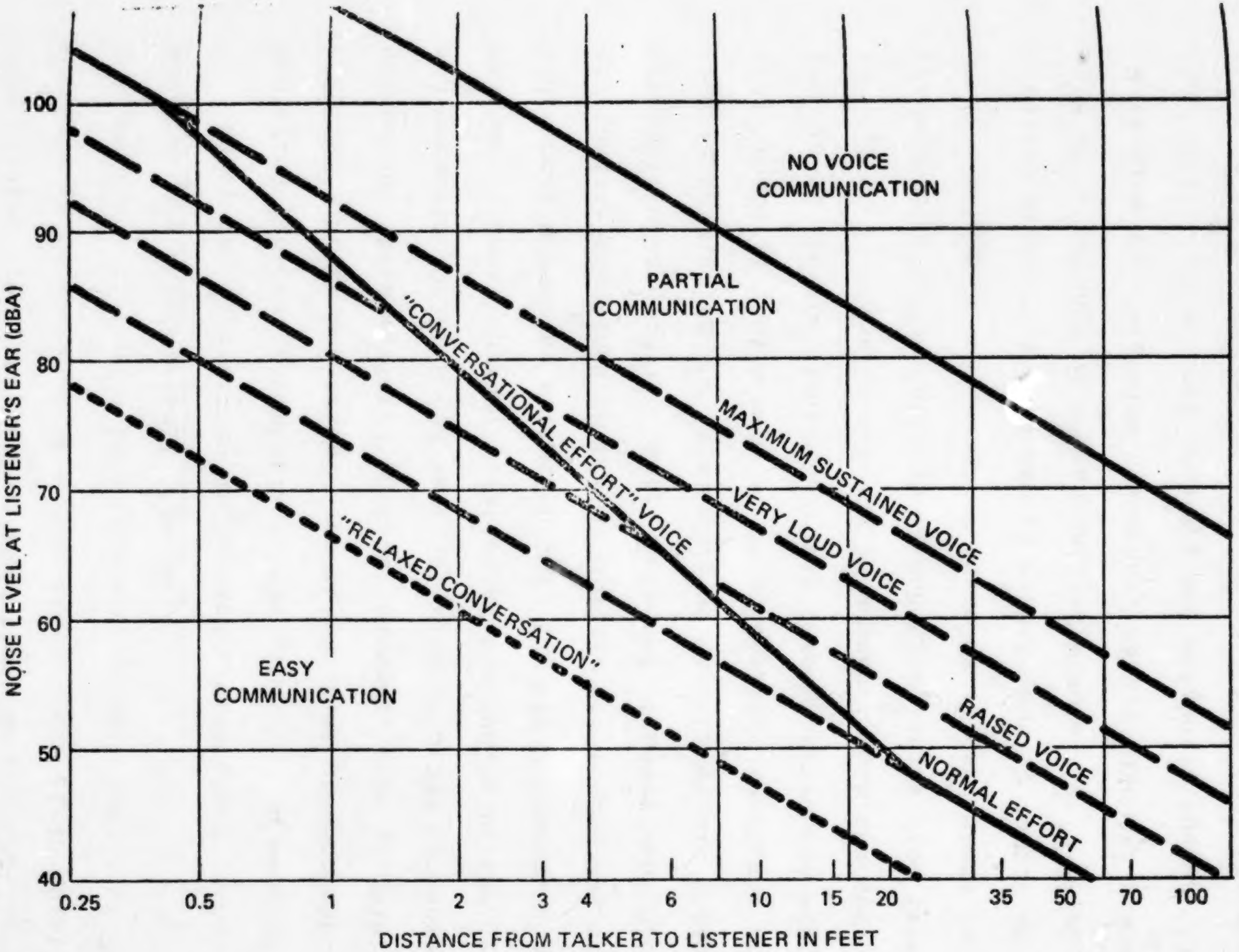


Figure 6-2. Distance at which ordinary speech can be understood (as a function of A-weighted sound levels of masking noise in the outdoor environment).

35 dB(A).[8,9,10] Specific investigations of the effects of noise from passing trucks on sleep showed that the probability of subjects being awakened by a peak sound level of 40 dB(A) was 5 percent and increased to 30 percent at peak levels of 70 dB(A).

Non-auditory Physiological Effects of Noise

Noise can elicit many different physiological responses including fatigue, irritability, and insomnia in some individuals.[7] Noise can trigger mechanisms that produce mental stress and stress-related physical changes, such as dilation and constriction of blood vessels, rise in blood pressure, changes in heart rhythm, dilation of the pupils of the eyes, additional endocrine secretion into the blood stream, ulcers and gastro-intestinal problems, migraine headaches, and other metabolic changes.[12,13] Even the sound of heavy vehicular traffic passing on the other side of the street can produce these changes. While most of these physical reactions are temporary, some may become chronic through prolonged exposure to noise. Although we may not be aware of such changes, such reactions may occur daily as we encounter noise from traffic. Since our bodies can interpret noise as stress, there is increasing evidence that noise is a contributing factor in the rate of occurrance of stress-related diseases,[7,12,14] such as heart disease, migraine headaches, cardio-vascular disfunction, gastro-intestinal problems and metabolic change. Although there is no conclusive evidence at this time that the above described reactions to noisy environments can lead to harmful consequences over a period of time, there also exists no conclusive evidence to the contrary. Thus, environmental noise must be considered a potential threat to our health and welfare, and therefore, must be abated and/or controlled.

. Susceptible Population Groups

A search of the technical literature for this report revealed insufficient data to permit stratification of the population at risk for either hearing loss or annoyance. There are no existing data which evaluate whether the adversive impact of noise pollution vary for socio-economic groups. Sensitive persons are comparably easily defined and denoted in regard to certain other forms of pollution (e.g., the sensitivity of elderly persons, persons with emphysema, and asthmatics to air contamination). Noise exposure presents a formidable problem since there does not appear to be an absolute zero level of noise in the environment or complete absence of response. For example, a very low level sound environment can be very distressing to some persons. This is not the case with air or water pollution in which both can be purified beyond the biologically threatening level. Furthermore, there does not seem to be adequate indication that there exists a readily identifiable group or sets of groups within the population who are "peculiarly sensitive, due to physical or psychological infirmities, to low levels of environmental noise."[7] However, it is clear that individual susceptibility varies greatly.

6.2.2 Present Day Impact Due to Environmental Noise

The day-night sound level, L_{dn}, has been specifically developed as a measure of community noise. Since it is a cumulative energy measure, it can be used to identify areas where noise sources operate continuously or where noise sources operate intermittently but are present enough of the time to emit a substantial amount of sound energy in a 24-hour period. An outdoor L_{dn} of 55 decibels (dB) is identified as the day-night sound level requisite to protect the public from long-term adverse health and welfare effects with an adequate margin of safety in residential areas.[2] However, this identified level was determined without regard to the economics and technology of noise reduction, and thus, should not be considered as immediately attainable or desirable under all circumstances.

The estimated number of people in residential areas who are subjected to urban traffic noise and freeway traffic noise at or above an outdoor L_{dn} of 75, 70, 65, 60, and 55 dB is shown in Table 6-4. As indicated by this data, it is estimated that more than 98 million people in residential areas are subjected to noise at or above the outdoor L_{dn} of 55 dB caused primarily by urban and freeway traffic. The study in which these estimates were made concentrated on sites away from major environmental sources of noise other than traffic. At the lower L_{dn} levels other environmental sources may have been minor contributors.

Table 6-4
Estimated Number of People Subjected (in millions) to Traffic Noise

At or Above Outdoor Ldn	Urban Traffic Noise	Freeway Traffic Noise
55	93.4	4.9
60	59.0	3.1
65	24.3	2.5
70	6.9	1.9
75	1.3	0.9

6.2.3 1975-1980 Situation

The general goal of a national noise abatement program is to reduce the impact of noise pollution in the United States.

Table 6-4 shows the estimated number of people in residential areas who are currently subjected to urban and freeway traffic noise at or above an outdoor L_{dn} of 55 dB. Two distinct conclusions can be made from this Table. Over 98 million people in urban areas are estimated to be exposed to noise from surface transportation equipment at or above L_{dn} 55 dB. Secondly, the number of people exposed to urban traffic noise far exceeds the number exposed in residential areas to the same noise levels due to freeway traffic. It may also be noted that only a very small percentage of the residential population is impacted by outdoor L_{dn} levels above 70 dB. As discussed in Section 6.2.2, since indoor noise levels will be 10 to 15 dB lower than outdoor noise levels even for the less substantially constructed family dwellings with open windows, virtually none of the traffic noise impacted residential population receives a dose greater than Leq (24) = 70 db which is the level above which a risk of hearing damage exists.

Effective reduction of urban noise is predicated upon the reduction of urban traffic noise. The median traffic noise level in a city is the result of noise generated by several sources, with the major sources identified as:

- Heavy Duty Trucks
- Medium Duty Trucks
- Buses
- Motorcycles
- Automobiles and Light Trucks

The relative impact of each of these sources can be obtained by taking into account their median noise levels and the traffic mix contributing to the total urban environment. Table 6-5 shows the median drive-by noise levels and relative mix of transportation noise sources. The median level of automobile noise emissions were calculated from data measured at 50 feet under both urban acceleration and normal cruise (27 mph) conditions.[15,16] Urban acceleration is that experienced by the average driver traveling in urban stop and go traffic.[15]. Noise levels measured in accordance with SAE J986a[17] procedures (maximum accelerating test) range 10 to 12 dBA higher than those observed under typical city acceleration conditions.[24] The noise levels for trucks, buses, and motorcycles represents an average of noise data emitted by these vehicles under urban acceleration (20 percent) and 27 mph road load (80 percent) conditions.[18,19] The median level for the automobile was calculated on the basis of data indicating 17% urban acceleration and 83% low speed cruise.[22] Separate noise values for the two modes are also indicated in Table 6.5.

Table 6-5
Current Median Noise Levels and Urban Traffic Mix

Source	Noise Level dB(A) at 50 ft	%Mix
Heavy Duty Trucks	85	1.0
Medium Duty Trucks	77	6.0
Buses	79	0.5
Motorcycles	82	1.0
Automobiles	65	91.5
Automobiles (Cruise at 27 mph is 60 dBA (Urban acceleration is 72 dBA)		

Relative traffic mix was calculated from data obtained from extensive investigations studying traffic in the urban environment.[18,20] Hence, the relative proportion of automobiles in urban areas is notably higher than would be anticipated from data on national vehicle miles traveled since the latter includes vehicle miles for both urban and highway travel. Only the noise impact of automobiles within urban environments is considered in this analysis due to the relative smaller magnitude of impact accorded to vehicles traveling on freeways.

6.3 Issues. Automobile Noise Sources

Exhaust -- For most automobiles, exhaust noise constitutes the predominant noise source for normal operation at speeds below the range of 35 to 45 mph, depending upon the condition and design of the exhaust system.[16] Above this speed tire noise generally becomes equally significant.

Fan Noise -- In some cases, the intensity of fan noise is almost equal to that of exhaust noise. The parameters which govern fan noise generation are essentially tip speed, shroud clearance and aerodynamic design. Considerable work has been done in the passenger car area to reduce noise in the passenger compartment, hence quiet fans have been available for some time.

However, the extensive use of air conditioners in modern automobiles has placed added loads on the cooling system from air conditioners, requiring increased fan rotational speed and in many cases increased noise.

Engine Noise -- Nearly all passenger cars utilize four-cycle gasoline powered engines which for the most part (smaller cars to a lesser extent) normally operate at a fraction of their rated horsepower output and thus produce minimum engine mechanical noise. In addition, automobile engines are well shielded on all sides, which serves to limit the amount of directly radiated noise. However, engine mounting is one of the important considerations in automobile design. Improper mounting may transfer some of the engine vibrations to the vehicle body which may, under certain conditions, produce higher noise levels than the engine body itself.

Intake Noise -- Air intake noise in automobiles constitutes a minor problem in achieving current and projected automobile noise requirements. The noise control principles are well understood by automotive engineers as evidenced by current air cleaners that are large enough to achieve adequate silencing with minimal air restrictions.

Tire Noise -- Tire noise is a function of road texture, surface wetness (wet roads may increase noise levels 10 dB)[21] and tread design. Tread designs for passenger car tires can be categorized into three basic types -- continuous rib, discrete block, and cross bar. Typical original equipment automobile tires utilize either a continuous rib or a discrete block tread pattern; generally, snow tires utilize a cross-bar pattern.

Broadly speaking, it is possible to divide tire noise into two categories, the first of which is tire noise radiated by the tire into the surrounding atmosphere. The second category results from tire vibrations transmitted through the vehicle's suspension and chassis to its body, and perceived by the vehicles's occupants as tire noise. This latter structure-borne transmission of vibrations has received much attention from automobile designers with the result that with well balanced tires, car tire noise above 400 Hz is transmitted principally by airborne paths.

There are four basic mechanisms of air radiated tire noise. These are squeal, tire vibration, aerodynamic effects and air pumping from the tread. Squeal is generally attributed to tread element vibrations, and is the noise generated by a tire during severe cornering, braking or acceleration. Road roughnesses and tire dynamic properties can excite a tire into complex vibrations which thereupon radiate sound.

The aerodynamic source is similar to the mechanism induced in rotating disc noise. Air pumping refers to the theory that tires produce noise by the entrapment and subsequent release of air in the cavities between adjacent tread elements. The theory derives its name from the air release process, which is likened to a pumping phenomenon. At speeds under 35 mph, aerodynamic effects generally make the least contributions to tire noise. Air pumping mechanisms produce widely varying levels depending on tire tread design, wear, and roadway surface.

Recent studies have shown that although smooth road surfaces reduce tire noise, there is a limit beyond which tire noise starts increasing because the entrapped air between the treads finds it increasingly difficult to escape. Considerations of safety also limit the ultimate road surface smoothness. The question of safety also needs to be addressed when designing quieter treads. If all treads were removed, the only remaining noise contributors would be the aerodynamic sources and tire surface vibrations.

Other aspects of tire noise radiation that are important are its directivity and tonality. The noise radiation pattern of a coasting vehicle is oval shaped, the level along the path of vehicle travel being about 5 dB higher than on the sides. The radiation pattern, combined with the motion of the vehicle, results in a measured drop of about 5 dB per doubling of distance from the vehicle path. Regulations limiting sideline noise levels of tires would thus result in somewhat higher levels fore and aft.

Under urban speed conditions of 30 to 35 mph cruise, rib type passenger car tires produce noise levels below 65 dB(A).[19] Tests on bald untextured tires at comparable speeds indicate levels of 56-58 dB(A), which appears to be the currently feasible minimum tire noise level in this speed range.[23] However, at lower speeds typical of urban, non-highway, high density stop and go driving, tire noise would be substantially lower. Some data indicates that total vehicle noise including tire noise, is in the range of 50 to 55 dB(A) at 10 to 20 mph cruise, implying lower or equal tire noise.[23]

6.4 Potential Noise Improvements from Regulatory Trucks, Buses, and Motorcycles

Immediately after the enactment of the Noise Control Act of 1972, EPA identified transportation noise sources as major contributors to outdoor noise pollution and promulgated the first surface transportation noise regulation, "Noise Emission Standards for Motor Carriers Engaged in Interstate Commerce," October 29, 1974. These standards specify a maximum level of 86 dB(A) measured at 50 feet from the centerline of lane of travel on highways with cruise speed limits of 35 mph or less; and 90 dB(A) on highways with cruise speed limits of more than 35 mph.

The EPA issued (October 30, 1974) a Notice of Proposed Rulemaking that would limit the noise emissions of new medium- and heavy-duty trucks, having a GVWR of 10,000 pounds or greater, to the levels listed below:

January 1977, 83 dB(A)
January 1981, 80 dB(A)
January 1983, 75 dB(A)

The levels are applicable to all trucks produced after the stated dates, and extend throughout the useful life of the truck. The measurement procedure is similar to SAE J366b; i.e., full throttle.[21]

Transportation product categories that have been identified in 1975 as major sources of noise and hence likely to be regulated in the near future (before 1978) are:

- Motorcycles
- Buses
- Truck Transport Refrigeration Units
- Truck-Mounted Solid Waste Compactors

Product categories planned for possible regulation in the 1977-1980 time frame are:

- Automobiles
- Light Trucks
- Tires

It is estimated that median noise levels from truck, bus, and motorcycle passbys in the 1980's after regulation of these vehicle will be approximately 71 dBA, 75 dBA and 78 dBA, respectively.[18] Again, this represents an average of accelerating and 27 mph road load data. Similarly, noise emissions for these vehicles, in the urban accelerating mode only, are reasonably estimated at 74 dBA, 78 dBA, and 78 dBA, respectively (see Table 6-6).

Table 6 -6
Anticipated
Median Passby Noise Levels

	Present*	After Regulation*	After Regulation (Acceleration Mode Only)
Heavy Duty Trucks	85	71	74
Medium Duty Trucks	77	71	74
Buses	79	75	78
Motorcycles	82	78	78

* Represents average of 27 mph road load and urban acceleration data.

6.5 Noise - Projection of Potential Benefits from Automobile Noise Emission Reduction

The projection of potential benefits which could be derived from reductions of automobile noise emission levels are described in terms of the percent reduction in the extensiveness and severity of noise impact as determined from changes in the equivalent number of people impacted (Peq). As discussed in Appendix B , the Peq descriptor represents the number of people adversely impacted by noise after appropriate weighting for the severity of individual noise exposure. The Peq is determined from predictions of the reduction in average traffic noise levels resulting from lowered noise emissions from individual mobile sources.

The potential health and welfare benefits resulting from reductions of automobile noise are presented below for urban street traffic only (medium to high density urban setting with stop-and-go driving and periods of maximum acceleration and low speed cruise), since (1) the number of people impacted by urban street traffic is much greater than the number impacted by freeway traffic noise, and (2) it is assumed that freeway noise will be substantially reduced by tire noise regulations in addition to vehicular propulsion noise.

Traffic noise levels are predicted by averaging median noise levels, expressed in terms of acoustic energy, emitted from buses, motorcycles, medium and heavy duty trucks, and automobiles (including light duty trucks).

6.5.1 Automobile Noise Emission Reduction Scenarios

Various noise reduction scenarios are presented below based upon both current and anticipated median noise levels emitted from vehicles identified above for both the 27 mph road load and acceleration conditions. Reductions of their respective noise levels are based upon recently promulgated regulations and/or regulations currently being developed; specific noise emission levels were given in Sections 6.2.3 and 6.4.

The total acoustic energy from each type of traffic noise source is calculated by considering a standard traffic mix of 91.5 percent automobiles, 6 percent medium duty trucks, 1 percent heavy duty trucks, 1 percent motorcycles, and 0.5 percent buses[20] as shown in Table 6.5.

The scenarios presented assume that automobiles are in the urban acceleration mode a maximum of 17 percent of the time.[22] The urban acceleration noise is considered to be 9 dB(A) lower than maximum acceleration as measured by SAE standard J986(a). The term acceleration used in the scenarios refers to urban acceleration. They further assume that the distribution of roadside passby noise levels (measured at 50 feet) as a function of time are approximated by a normal (Gaussian) distribution. This latter assumption implies a steady stream of closely spaced vehicles of varying types; the steady stream can consist of vehicle movement in two directions. Normal operation of vehicles is also assumed[16] (no vehicle misuse, i.e., drag racing, etc.)

Scenario A

The minimum possible urban traffic noise impact resulting from automobile noise emissions is considered here. The scenario assumes that all automobile noise is reduced to 0 dB(A) and all other transportation categories - heavy and medium duty trucks, buses and motorcycles - remain at their current unregulated noise levels. The result, presented in Figure 6.3, shows a 20% reduction in traffic noise impact without the regulation of other vehicles.

Scenario B

In this scenario, all transportation categories, except automobiles, are assumed to be regulated to levels discussed in Section . Automobile acceleration noise is incrementally reduced, while the noise emitted under a 27 mph road load condition remains constant at 60 dB(A). The results of this analysis are also presented in Figure 6.3 and show a reduction of about 20% in noise impact from reducing automobile acceleration noise from 72 to about 60 dBA.

Scenario C

This scenario assumes all transportation categories, except automobiles, are regulated to levels discussed in Section 6.4. Both automobile acceleration noise and normal low speed cruise noise are then concurrently reduced over incremental steps, with the latter generally 10 dB lower than the acceleration levels. The results of this analysis are also presented in Figure 6.3. Note that the emission levels under the normal cruise mode at 27 mph are shown in parenthesis.

Scenario D

This scenario is applicable to those areas where trucks. buses, and motorcycles may be prohibited or are rarely found. Hence, traffic noise is totally attributable to automobiles. Reduction in noise impact as a function of reductions in automobile acceleration noise is shown in Figure 6.4. Again, the ordinate represents percent reduction in impact, while the abscissa is the reduction of automobile noise under acceleration conditions leaving noise emitted under normal cruise constant at 60 dB(A).

Scenario E

This scenario is identical to that of Scenario D except that the impact is determined as a function of concurrent reduction of automobile acceleration and normal cruise noise. The results of this analysis are also presented in Figure 6.4.

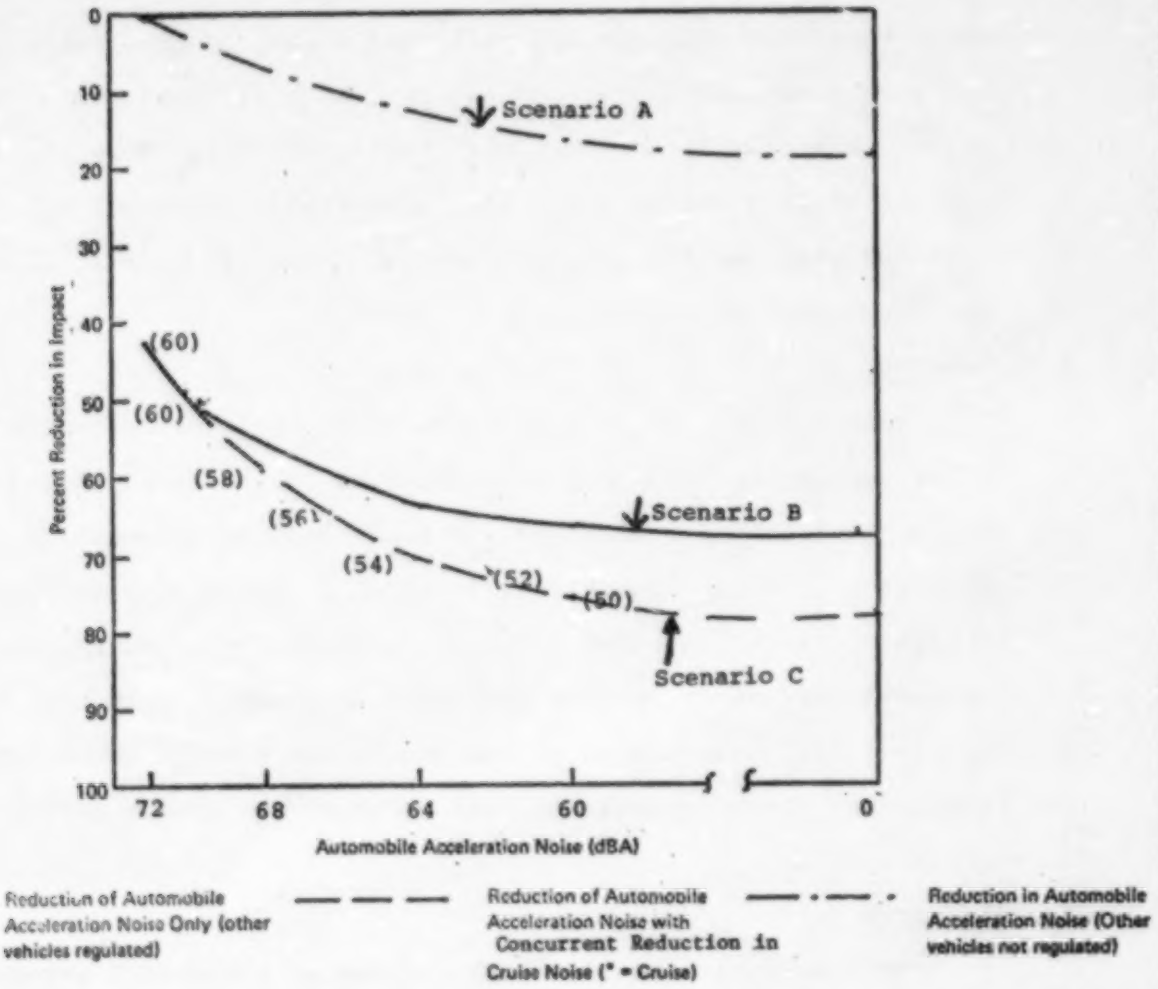


FIGURE 6-3
Reduction in Noise Impact as Function of Decreasing Automobile Acceleration Noise in Presence of Other Mobile Noise Sources

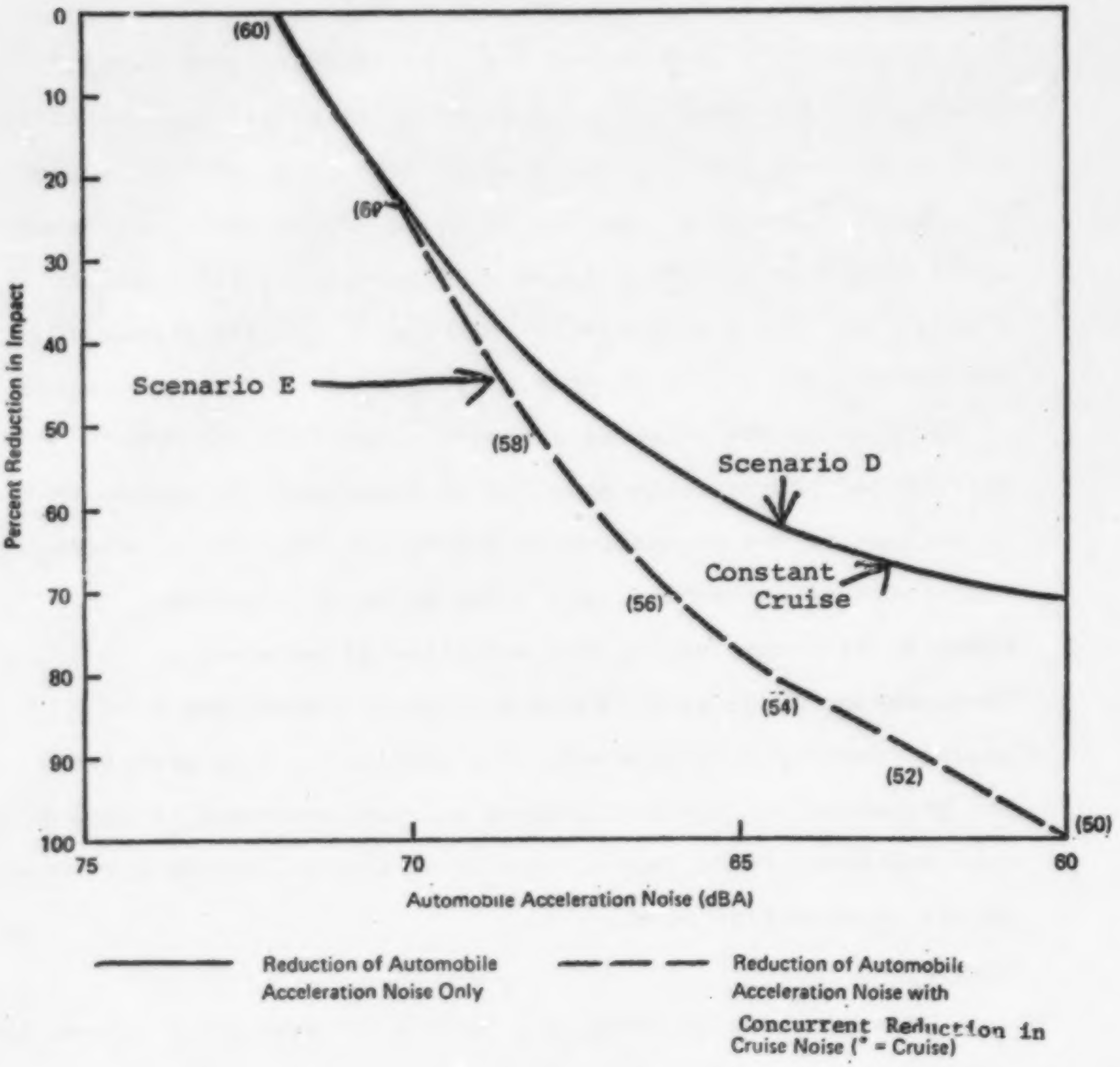


FIGURE 6-4
Noise Impact Reductions for Urban Areas
Limited to Automobile Traffic Only

Scenario F

The benefits of reducing the more annoying peak levels[4] attributable to automobile acceleration noise are determined for that segment of the population exposed to only vehicle acceleration noise. Assuming that (1) vehicles accelerate at the same fixed locations within an urban environment (attributable to starts from stop signs, traffic signals or turning corners), (2) automobiles are in an accelerating mode at least 17 percent of the time in the urban environment,[21] and (3) population is evenly distributed in the urban area, it is reasonable to assume that 17 percent of the population is exposed to only the acceleration noise of automobiles and other types of vehicles. This scenario is evaluated for the condition of automobile acceleration noise reduction with trucks, buses, and motorcycles remaining unregulated. The results of this analysis are presented in Figure 6.5 where percent reduction in extensiveness and severity of impact is plotted against automobile noise in the acceleration mode.

Scenario G

This scenario is identical to that of scenario F except the reduction in impact is calculated assuming trucks, buses, and motorcycles are regulated. The results of this analysis are also presented in Figure 6.5.

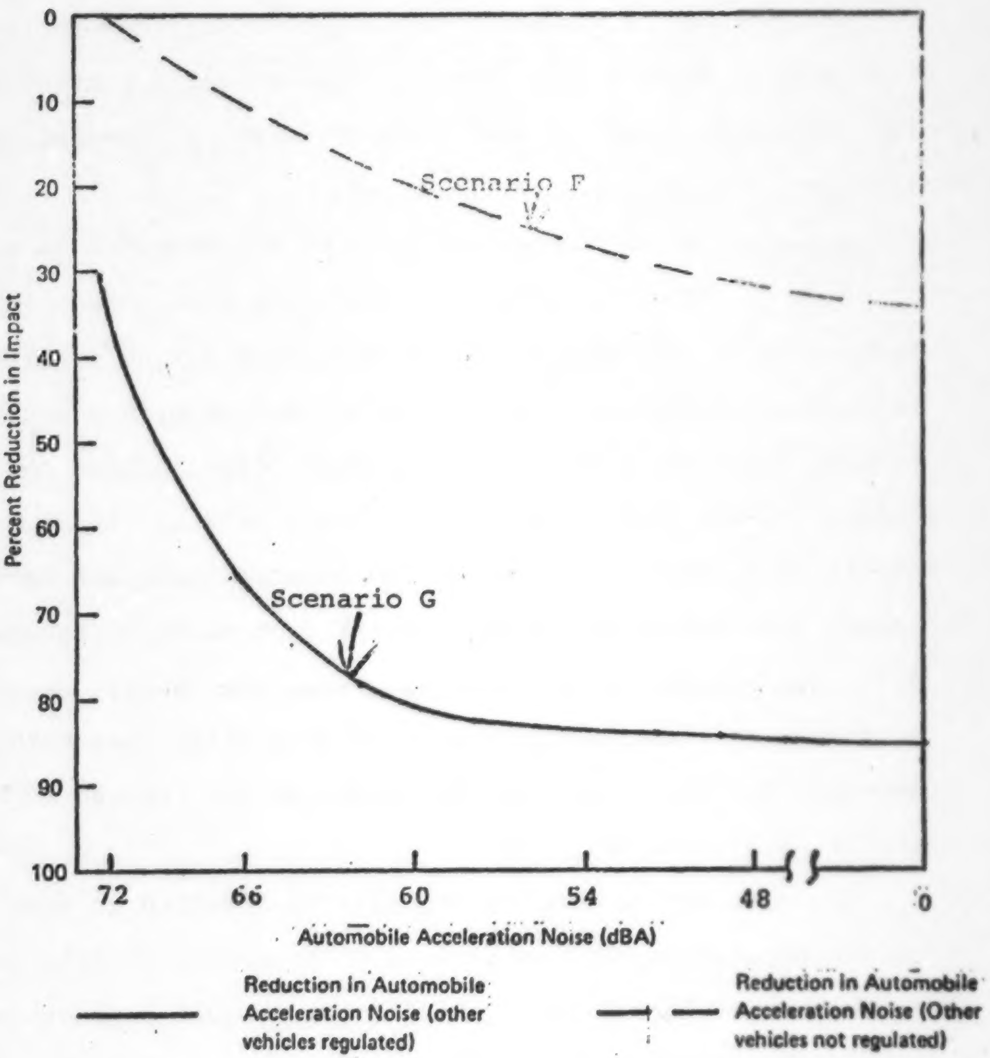


FIGURE 6-5
Reductions in Noise Impact to Persons
Exposed to Vehicle Acceleration Noise Only

6.5.2 Conclusions

The results in Figures 6-4 and 6-5 clearly demonstrate the fact that effective reduction of urban noise is contingent upon the regulation of noise emissions from all surface transportation vehicles, not just automobiles.

Although primary benefits in terms of reduction in extensiveness and severity of noise impact are associated with reductions of automobile noise under accelerating conditions, substantial additional benefits are realized by a concurrent program reducing noise emissions under normal cruise condition Figure 6-3 and 6-4). Specifically, the data in Figure 6-3 exhibits 66 percent reduction in the extensiveness and severity of impact when automobile urban acceleration noise is reduced to 60 dB(A) (an average of 11 dB(A) less than SAE J986a), while a 75 percent reduction in impact is achievable when both accelerating and normal cruise emissions are reduced to 60 dB(A) and 50 dB(A), respectively.

The most substantial relief will be afforted to that segment of the population that is exposed to primarily vehicle acceleration noise, culminating in an 80 to 87 percent percent reduction in impact when urban accelerating levels are reduced below 60 dB(A). Furthermore, very substantial benefits can be realized by those people primarily exposed to automobile noise, i.e., in those areas where trucks, buses, and motorcycles are either prohibited or do not normally operate. Benefits in this latter case are approximately a 72 percent reduction in noise impact when acceleration noise is reduced to 60 dB(A) (Average of 71 dB(A) under SAE J986a) and 100% reduction (no impact) when levels are reduced to 60 dB(A) and 50 dB(A) for urban acceleration and cruise modes, respectively. Of particular note is the fact that completely eliminating automobile noise would effect only an approximate 78 percent reduction in noise impact to the whole population, and 88 percent relief to that portion of the population exposed to only vehicle acceleration noise; where a vehicle mix including about 9% of trucks, buses and motorcycles is allowed to operate.

In view of the above results, an effective long-term health and welfare objective for automobile noise emissions, as measured at 50 ft, without regard to economic or technological feasibility, is in the range of 60-64 dB(A) for passby acceleration noise (corresponding to approximately 71-75 dB(A) under SAE J986a). Additional benefits may be realized if noise emissions are reduced such that at typical urban cruise, automobiles emit only 50-56 dB(A) as observed at 50 feet (no relationship can be drawn to SAE J986a). While attaining such a level would seem to be handicapped by tire noise, it should be noted that in substantial portions of major urban areas with high population densities, the assumed vehicle cruise speed of 27 mph is too high. For example, at low speeds (10 to 20 mph), urban acceleration and cruise noise will be predominant over tire noise with vehicles in the acceleration mode considerably in excess of the assumed 20 percent.

Appendix A

Definition of Leq and Ldn

Environmental noise is defined in the Noise Control Act of 1972 as the "intensity, duration, and the character of sounds from all sources." A measure for quantifying environmental noise must not only evaluate these factors, but must also correlate well with the various modes of response of humans to noise and be simple to measure (or estimate).

An equivalent A-weighted sound level in decibels has been selected as a general measure for environmental noise. The general symbol for equivalent level is Leq, and its basic definition is:

$$L_{eq} = 10 \log_{10} \left\{ \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} \frac{p^2(t)}{p_o^2} \cdot dt \right\}$$

where $t_2 - t_1$ is the interval of time over which the levels are evaluated, p(t) is the time varying sound pressure of the noise, and p_o is a reference pressure, standardized at 20 micropascals. When expressed in terms of A-weighted sound level, L_A, the equivalent A-weighted sound level, Leq, may also be defined as:

$$L_{eq} = 10 \log_{10} \left\{ \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} 10^{\left[L_A(t)/10\right]} \cdot dt \right\}$$

There are two time intervals of interest in the use of Leq for impact assessment. The smallest interval of interest for vehicle noise on highways is one hour, often the "design hour" of a day. The primary interval of interest for residential and similar land uses is a 24-hour period, with a 10 dB weighting applied to nighttime noise levels to account for the increased sensitivity of people associated with the decrease in background noise levels at night. This 24-hour weighted equivalent level is called the Day-Night Equivalent Level, and is symbolized as Ldn. The basic definition of Ldn is terms of the A-weighted sound level is:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \cdot \left\{ \int_{0700}^{2200} 10^{L_A(t)/10} \cdot dt + \int_{2200}^{0700} 10^{(L_A(t)+10)/10} \cdot dt \right\}$$

or

$$L_{dn} = 10 \log_{10} \frac{1}{24} \cdot \left[15 \times 10^{L_d/10} + 9 \times 10^{\left(L_n+10\right)/10} \right]$$

where L_d is the equivalent level obtained between 7a.m. and 10p.m. and L_n is the equivalent level obtained between 10p.m. and 7a.m. of the following day.

Appendix B
Fractional Impact Analysis

The underlying concept for noise impact assessment is to relate the change in expected impact, in terms of number of people involved, to the change expected in the acoustical environment. Three fundamental components, are involved in the analysis: (1) definition of initial acoustical environment, (2) definition of final acoustical environment, and (3) relationship between any specified noise environment and expected human impact. [22]

The first two components of the assessment are entirely site or system specific, relating to either estimates or measurement of the environmental noise before and after an action is taken. The same conceptual approach is used, for example, whether one is examining a single house near a highway, a house near an airport, the transportation system in general, or whatever noise sources are involved. The methodology for estimating the noise environment will vary widely with the scope and type of problem, but the concept remains the same.

In contrast to the widely varying possible methodologies that may be utilized to estimate the noise environment, the relationships to human response can be quantified by a single methodology for each site or noise producting system such methodology must consider the number of people in occupied places exposed to noise of a specific magnitude. This is not to say that individuals have the same susceptability to noise; they do not. Even groups of people may vary in response, depending upon previous exposure, age, socio-economic status, political cohesiveness, and other social variables. In the aggregate, however, for residential locations the average response of groups of people is quite stably related to cumulative noise exposure as expressed in a measure such as L_{dn}. The response considered is the general adverse reaction of people to noise. This response is a combination of such factors as speech interference, sleep interference, desire for a tranquil environment, and the ability to use telephones, radio, and television satisfactorily. The measure of this response is related to the percent of people in a population that would be expected to indicate a high annoyance to noise at a specified level of noise exposure.

A detailed discussion of the different forms of response to noise such as hearing damage, speech or other activity interference, and annoyance and their relationship to L_{eq} and L_{dn} is presented in the EPA Levels Document.[2]

Criteria presented in the EPA Levels Document provide the basic quideline with respect to noise impact.[2] Thus, if the levels identified in the Levels Document are met, no impact exists. That is, if an Ldn of 55 dB measured outdoors exists, then there is no impact in terms of general annoyance and community response due to noise. Similarily, if an Ldn of 45 dB exists indoors (corresponding to an Ldn of 55 dB outdoors assuming a 10 dB transmission loss with the window partially opened), there occurs, on the average, 100 percent speech intelligibility for all types of speech material.

The intelligibility for sentences (first presentation to listeners) drops to 90 percent when the level of the noise environment is increased by approximately 19 dB above the identified level, and to 50 percent when the level is increased by approximately 24 dB. The intelligibility for sentences (known to listeners) drops to 90 percent when the level is increased by approximately 22 dB above the identified level, and to 50 percent when the level is increased by approximately 26 dB.[2] Thus, considering that normal conversation contains a mixture of both types of material, some new and some familiar, it is clear that when the level of environmental noise is increased by more than 20 dB above the identified level, the intelligibility of conversational speech deteriorates rapidly with each decibel of increase. For this reason, a level which is 20 dB above the identified level is considered to result in 100 percent impact on the people who are exposed. For environmental noise levels which are intermediate between 0 and 20 dB above the identified level, the impact is assumed to vary linearly with level; i.e., a 5 dB excess constitutes a 50 percent impact.

A similar conclusion can be drawn from the community reaction and annoyance data contained in Appendix D of the Levels Document[2]. The data generally show no community reaction to an identifiable source of intruding noise when its day-night sound level is at least 5dB below the prevailing day-night sound level. When the noise from this source is capable of raising the prevailing day-night sound level by 20 dB, vigorous community action generally occurs. Thus, 20 dB is a reasonable value to associate with a change form 0 to 100 percent impact. Such a change in noise level would increase the percentage of the exposed population which is highly annoyed from relatively few people to over 45 percent of the total exposed population.

For convenience of calculation, these percentages may be expressed as fractional impact (FI). An FI of 1 represents an impact of 100 percent, in accordance with the following formula:

$$FI = 0.05\ (L - Lc) \text{ for } L > Lc$$

$$FI = 0 \text{ for } L \leq Lc$$

where L is the appropriate L_{eq} for the environmental noise and Lc is the appropriate identified criterion level. FI can exceed unity for exposures greater than $L_{dn} = 75$.

As discussed previously, to evaluate the impact of the noise of motor vehicles on people living in residential areas, the appropriate identified level is an L_{dn} of 55 dB, which exists outdoors. For other analyses concerned with office buildings and other types of spaces when indoor speech communication is the principal factor of concern, the appropriate identified criterion level is an L_{dn} of 45 dB (indoors), which, in this analysis, translates to an outdoor L_{dn} of 55 by using an appropriate sound level reduction to account for building transmission loss.

The final notion to be considered is the manner in which the number of people affected by environmental noise is introduced into the analysis. The magnitude of total impact associated with a defined level of environmental noise may be assessed by multiplying the number of people exposed to a given level of environmental noise by the fractional impact associated with this level as follows:

$$P_{eq} = (FI)P$$

where P_{eq} is the magnitude of the impact on the population and is numerically equal to an equivalent number of people which would have a fractional impact equal to unity (100 percent impacted). FI is the fractional impact for the defined level of environmental noise and P is the population exposed to this level of environmental noise.

When assessing the total impact of a given noise source or an assemblage of noise sources, the levels of environmental noise associated with the source(s) decrease as the distance between the source and receiver increase. In this case, the magnitude of the total impact may be computed by determining the number of people exposed at each level, and summing the resulting impact. The total impact is given by the following formula:

$$P_{eq} = \sum_i P_i \cdot F\,I_i$$

where FI is the fractional impact associated with the i^{th} level and P is the population associated with the i^{th} level.

The change in impact associated with an action leading to noise reduction, or change in population through a change in land use, may be assessed by comparing the magnitude of the impacts for the "before" and "after" conditions. One useful measure is the percent reduction in impact (Δ), which is calculated from the following expression:

$$\Delta = 100 \frac{(P_{eq}\,(\text{before}) - P_{eq}\,(\text{After}))}{P_{eq}\,(\text{before})}$$

Note that the percentage change may be positive or negative depending upon whether the impact decreases (positive percentage reduction) or the impact increases (negative percentage reduction).

Thus, a 100 percent positive change in impact means that the environmental noise has been reduced such that none of the population is exposed to noise levels in excess of the identified levels.

An example will place this concept in perspective. In the EPA study, "Population Distribution of the United States as a Function of Outdoor Noise Level[6]," an estimate is provided for the number of people in the United States exposed to various levels of urban noise. Using these data and the above concepts, the current impact of this exposure is determined and the change in impact, if all noise sources were reduced 5, 10, or 15 decibels, is assessed. In the following computation P_i is defined as the population between successive 5 decibel increments of L_{dn}. This population is assigned an exposure L_{dn} midway between successive L_{dn} annuli. For this example, the identified criteria level is an L_{dn} of 55 dB measured outdoors.

The results, presented in Table B-1 for that portion of the urban population removed from major specific sources other than general urban traffic, show that a 5 dB noise reduction results in a 55 percent reduction in impact, a 10 dB noise reduction results in an 85 percent reduction in impact and 15 dB noise reduction results in a 96 percent reduction in impact.

The impact assessment procedure, illustrated in Figure B-1, may be summarized by the following steps:

(1) Estimate the L_{eq} or L_{dn} produced by the noise source system as a function of space over the area of interest.

(2) Define subareas of equal L_{eq} or L_{dn}, in increments of 5 decibels, for all land use areas.

(3) Define the population P_i, associated with each of the subareas of step 2.

(4) Calculate the FI_i values for each L_{dni} and L_{eqi}, obtained in step 2.

(5) Calculate FI_i x P_i for each subarea in step 2

(6) Obtain the equivalent impacted population for the condition

Table B-1
Noise Reduction Results

Current Conditions			L_{dn} Noise Reduction in Decibels							
L_{dn}, dB	Population exposed to higher L_{dn}, millions	P_i millions	0		5		10		15	
			FI_i -	FI_iP_i millions	FI_i -	FI_iP_i millions	FI_i -	FI_iP_i millions	FI_i -	FI_iP_i millions
55	93.4	34.4	0.125	4.3	0	0	0	0	0	0
60	59.0	34.7	0.375	13.0	0.125	4.3	0	0	0	0
65	24.3	17.4	0.625	10.9	0.375	6.5	0.125	2.2	0	0
70	6.9	5.6	0.875	4.9	0.625	3.5	0.375	2.1	0.125	0.7
75	1.3	1.2	1.125	1.4	0.875	1.1	0.625	0.8	0.375	0.5
80	0.1	0.1	1.375	0.1	1.125	0.1	0.976	0.1	0.625	0.1
Total Equivalent People Impacted				34.6		15.5		5.2		1.3
Percent Reduction in Impact				0		55		85		96

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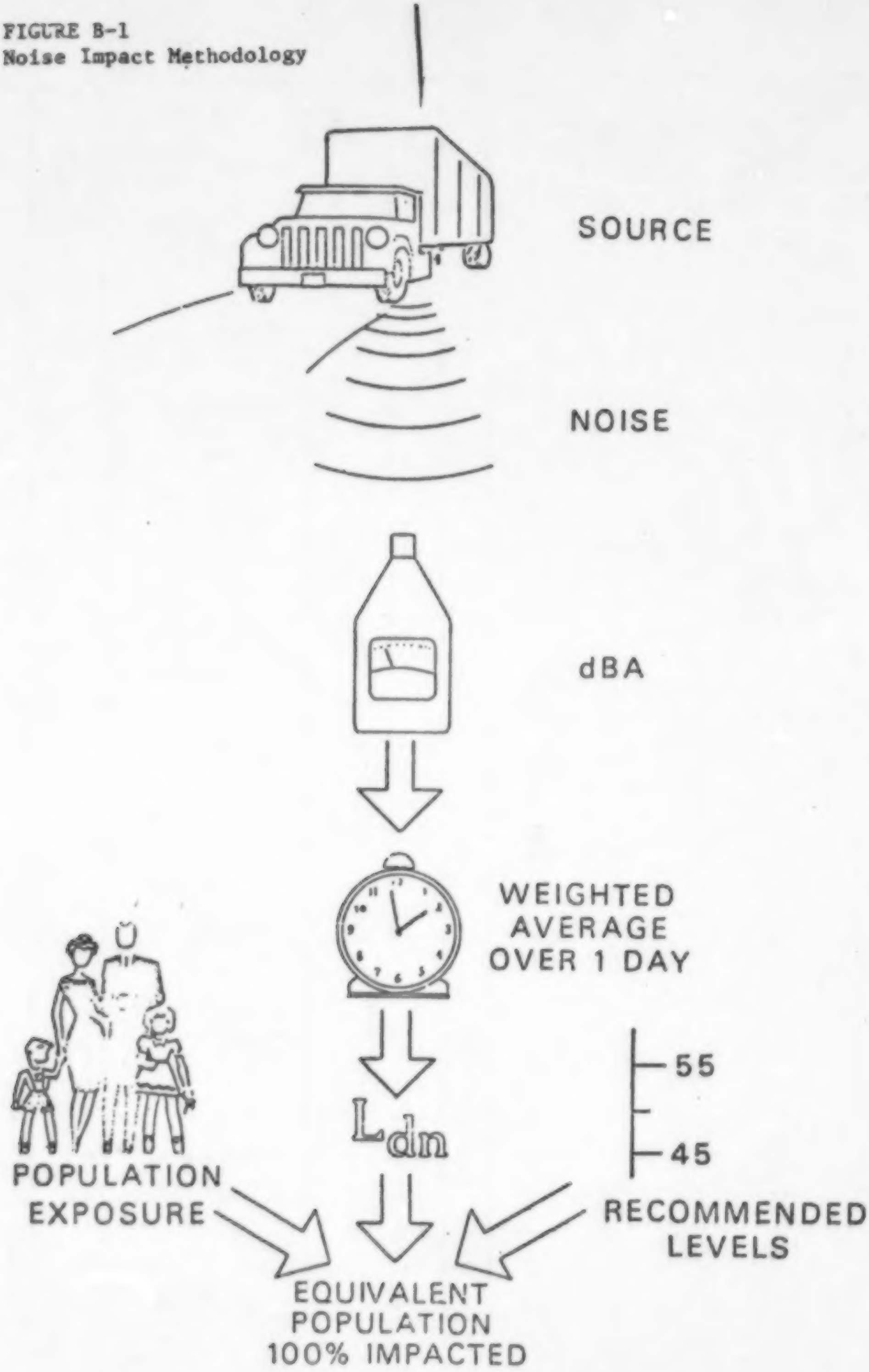
FIGURE B-1
Fractional Noise Impact Methodology


SOURCE
NOISE
dBA
WEIGHTED AVERAGE OVER 1 DAY
L_{dn}
POPULATION EXPOSURE
55
45
RECOMMENDED LEVELS
EQUIVALENT POPULATION 100% IMPACTED

existing before the change being evaluated,

$$P_{eq} = FI_i \times P_i$$

by summing the individual contribution of step 5.

(7) Repeat steps 1-6 for the noise environment existing over the area of interest after the change being evaluated takes place, thus obtaining P_{eq}. (Note that the subareas defined here will not in general be congruent with those of step 2 above).

(8) Obtain the percent reduction in impact from

$$\Delta = 100 \cdot \frac{P_{eq_B} - P_{eq_A}}{P_{eq_B}}$$

APPENDIX C

Projections of Urban Traffic Noise Levels to Year 2000

Urban traffic noise is a function of the vehicle mix, vehicle pass-by speeds, the "drive cycle" and to some extent on the number of vehicles. Using air pollution terminology, if the number of vehicle miles traveled (VMT) increases due to an increase in the number of vehicles on streets, we may expect that average urban noise levels would go up due to increased congestion contributing to more frequent acceleration and deceleration. However, unlike the air pollutants released by automobiles, noise pollution exists only while the source, i.e., the vehicle, is physically present, generally within sight of the observer.

Urban noise level increase has been predicted for a low VMT growth rate of 1 percent and a high VMT growthrate of 3 percent assuming no noise emission regulations. The assumptions made in calculating the noise levels are:

- Increase in vehicle miles traveled is solely due to increase in number of vehicles.
- The vehicle mix of 1 percent heavy duty trucks, 6 percent medium duty trucks, 0.5 percent buses, 1 percent motorcycles and 91.5 percent automobiles remains constant.

Based on these assumptions, a preliminary analysis indicates a 5 percent increase in extensiveness and severity of impact, under the 1 percent growth rate and 15 percent increase in impact under the 3 percent growth rate by the year 2000.

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